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THE

CIVIL ENGINEER AND ARCHITECT'S

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LECTURES ON ARCHITECTURE,

By Samuel Clegg, Jun., Esq.

DELIVERED AT THE COLLEGE FOR GENERAL PRACTICAL SCIENCE, PUTNEY, SURREY:

PRESIDENT, HIS GRACE THE DUKE OF BUCCLEUGH, K.G., ETC. ETC.

The Lecturer on Architecture proposing to deliver a course of lectures upon its history, monthly, in the Hall of the College, tracing the subject from its earliest origin to our own times, we have made arrangements for printing these interesting Lectures in *our Journal;* and we feel satisfied they will prove instructive, not only to the young student, but also to many of those more advanced in their profession.

We have the gratification of adding, that free access to these Lectures will be given to Members of the Institute of Architects, of the Institution of Civil Engineers, and to gentlemen being articled pupils in either of the professions, on application to the Reverend, the Principal of the College.

For the fees to the standing collegiate Architectural course, and also for that on Civil Engineering, we would refer our readers to the prospectus,—with our recommendation, that they personally make themselves acquainted with the system and means of instruction at an institution hitherto too little known, but which deserves public encouragement on account of the combination of theoretical and practical science which may be acquired simultaneously at this College.

Lecture I.—Introduction.—Egypt.

(*With an Engraving, Plate* I.)

History is universally allowed to be one of the most interesting and instructive studies that can occupy the attention of a thinking being. Not the mere chronicle of reigning monarchs and party factions; not the record of perpetually recurring war, with its consequent suffering and crime, but the history of the human race in its gradual development; of civilisation in its progressive and retrograde movements; of religion and commerce; of literature, art, and science: the history of all those things the cultivation of which have wrought the change from the ignorant savage, but little superior to the flocks and herds that clothed and gave him food, to the moral and intellectual man he was destined to become.

What can be more interesting than (standing as we do in the broad daylight of the 19th century) to contemplate the past,—to grope our way through the dark ages,—to pass in review the evening glories of Rome, the full blaze of noon in Greece, and the early dawn in Egypt and Assyria? In thus looking backwards, we find no art or science in which the genius of each succeeding age and country has so fully developed itself as in Architecture—the art, above all others, most useful and ornamental; adding at once to the safety and accommodation, and the delight and dignity of mankind. Architecture provides citadels for defence, habitations for private life, erects temples for worship, and theatres where we seek amusement; throws bridges over the otherwise impassable torrent, brings the refreshing stream from the distant mountain, raises monuments to our illustrious dead—and, in short, has its part in almost every comfort and luxury of life. Architectural remains present the only certain records we possess of several ancient nations: nor can we arrive at a better knowledge of a people separated from us by the interval of ages than by an examination of their buildings and monuments. Their temples speak to us of their faith and forms of worship; their palaces and courts of justice of their civil institutions; their triumphal arches and tripods and obelisks of their heroes and benefactors; their dwelling-houses of their domestic life; and their places of public assembly and amusement of the degree of civilisation and refinement to which they had attained. Under another point of view, also, the student will find himself well repaid by the study of the History of Architecture—*nothing* can tend in a greater degree to mature the judgment and refine the taste. Surely, in preparing ourselves for the practice of any art or science, and in order to carry it still farther towards perfection by our own endeavours, we ought to obtain a complete knowledge of those inestimable treasures with which the taste and genius of our forefathers has endowed us. But if we would really *learn*, we must approach this, like every other study, with a mind free from hastily-formed opinions, and unfettered by prejudice; we must be willing to admit excellence wherever it exists, and to perceive beauty wherever it is to be found, as well as to detect the barbarous and meretricious. We must recollect, in our examination of different styles, that no original forms were arbitrary or accidental; that wherever the manner of construction is suitable to the material—wherever the style of architecture corresponds with the climate, and is adapted to the sentiments and manners of the nation and of

the age—wherever it constitutes in its principal forms and in its details and ornaments an harmonious whole, rejecting everything inconsistent with and foreign to itself, there we may find something to learn from and to admire; nothing is to be condemned but what is inharmonious and unsuitable. These principles will assist in forming a judgment on the works of all ages and nations: bearing them in mind, we shall easily perceive where a style has been borrowed—where it has owed its origin to a different climate and different circumstances, by the character of unconnectedness and unsuitableness it is sure to retain; until some artist of pre-eminent genius steps in, and successfully forms out of the mass of collected material, a new, national, and consistent style of building.

What can be more sublime than the monuments of old Egypt, where, by simple grandeur of outline and sculptured symbol, a nation in the infancy of the world was struggling to express the childlike earnest veneration for the unseen and unknown around and about it?—or what more ludicrous than a miniature pylon in the crowded thoroughfare of a great city, or a dromos of minute sphinxes keeping watch over the door-scraper and snug entrance-hall of a retired citizen's suburban villa? What could be more beautiful than the glittering shafts of Pentelic marble, rising from some tall cliff, the landmark of the Greek adventurer on his homeward way, or gleaming in the sunlight from amidst the consecrated grove?—or what more unsuitable than an imitation of such a temple transplanted into the damp and foggy atmosphere of England, and misconstructed into doing service as a dwelling-house, with its portico to obstruct the scanty light, and low-pitched roof to lodge the rain and snow? Can anything be more glorious, more significant than the Gothic cathedral, with its flowing lines and multiplication of parts, leading the mind onward to thoughts of immensity and infinity; and shaft upon shaft, arch and tower and pinnacle rising for ever upwards, like the aspiration of the Christians?—or anything more appropriate to the spirit of the age than the stronghold of the feudal baron, with its battlements and watch-towers, the terror or protection of the surrounding district? But what shall we say of a cottage in the pointed Christian style, perhaps with the addition of a row of chimneys *à la Cinquecento*?—or of a castellated mansion, in every other respect probably, the very beau ideal of peace and security?

By the study of the History of Architecture, both excellencies and defects become more evident, so that I would dwell upon it not merely as an *engaging study*, but as one of the highest practical importance, both to the architect and amateur. It is interesting to find the high estimation in which the arts were held in ancient times. During the intervals of peace, the spoils of war and the thoughts and energies of rulers and people were dedicated to the adornment of the beloved native land.

In Egypt, the profession of artist was considered one of such importance, that no illiterate person was allowed to exercise it. Agamedes and Trophonius, princes of Orchomenes, in Boetia, received from their countrymen an apotheosis, in honour of their skill in the mechanical arts. And the Etruscan lucumones, or nobles, were not only the senators, and generals, and priests, but also the astronomers, engineers, and architects of their country. Wherever architecture has been encouraged, it follows naturally that painting and sculpture, and all the decorative arts, have flourished at the same time, and have been held in equal estimation.

Though we may imagine buildings to have been amongst the first wants of mankind, yet, from the probable slightness of material of those primitive constructions, our oldest architectural remains must date many centuries subsequent to the wooden or mud huts of the early races. In tracing the first steps in the art, therefore, we are left to mere conjecture. As we must suppose the first men living in a warm climate, we may also imagine that little more was necessary to them than what Nature had bestowed—the groves for shade and shelter, and the spontaneous productions of the soil for food; thus they lived without care or labour. But as mankind increased, it was necessary to disperse to procure a sufficiency of food; and colonies from the primeval tribe, wandering to colder or hotter regions where Nature was less liberal in her gifts, they were forced to think, to invent, to labour, in order to provide for their subsistence. We may suppose these early colonists divided into three classes—Hunters, Shepherds, and Agriculturists.

1st. The *Hunter*, leading a precarious and solitary life, dependent upon his own individual exertions, and frequently changing his haunts in following his prey, would, when wearied by day, content himself at night with a cave, or any other natural shelter, where he might prepare his food and recruit for the next day's toil. This is the rudest state of existence; nor do we find the Indian or New Zealander in a much greater state of civilisation than their most remote ancestors may have been.

2nd. The *Shepherd*, living a patriarchal life in the midst of his flocks and herds. As it was necessary for him to seek the open plain for pasturage, he could not have recourse to the rocks or forests for shelter; and as his was a wandering life, moving off to new districts as the supply of food was exhausted in the old, neither could he build himself a fixed habitation: therefore, we universally find a shepherd people living in tents—which, when required, could be removed with all the goods and chattels appertaining.

3rd. The *Agriculturists*—and it is to this class we must look for the first institutions of social life, and consequent progress of civilisation. The agriculturist was necessarily fixed to one spot; labour was divided, the industry of each became beneficial to the whole. As the community increased, a small portion of the population was found adequate to the tillage of the soil; the remainder must therefore devise some other method of profiting by their time and labour: man's energies were thus first called forth to create and supply artificial wants; members of society became dependent on each other, rights of property were acknowledged, exchange of commodities effected, and laws were framed to protect the weak against the strong. The increasing wealth of the community demanded additional means of safety; not only were houses required for the people, and buildings in which to store up the grain, but walls must be erected to protect the infant state from the incursions of their less industrious neighbours. A chief or king was chosen to enforce the laws, direct the councils, and lead the warriors; and as all were occupied with their several avocations, a priesthood was set apart to watch over the interests of religion, and offer up sacrifices to the gods: then altars or temples were erected in honour of the presiding deity, and a palace in which the chosen leader might reside with becoming dignity. Other habitations naturally multiplied around the altar and the palace: and thus the first cities originated. Frequently, in the earliest times, the king was at the same time high-priest; and then we find, as in Egypt, the palace and temple in one, and the hall of justice an essential part of the edifice. Gradually as one city arose after another, communication was opened between them by land and sea, and roads and harbours were constructed. Some united together under one chief for mutual protection, others were offshoots from the mother city, always acknowledging her as their metropolitan: thus kingdoms were formed, and civilisation progressed—not only in time of peace, but in this infant state of society even more rapidly in time of war,—the conquerors adding the arts and learning of the conquered to their own previously acquired knowledge. It is this transmission and diffusion of ideas that makes it so difficult to point to the exact origin of any art or science, and has caused so many dissertations, whether to Egypt, to Phœnicia, or to India, we owe the first advance in the march of human progress. Letting this question rest, I prefer to speak of Egypt first, as we have more ancient, authentic, and copious records of this, than of any other nation of antiquity.

Egypt will always claim a high place in our interest. To quote the words of Mr. Sharpe, after speaking of the histories of the Jews, of Greece, and of Rome, he says: "After these three histories, that of Egypt may certainly claim the next place, from the influence which that remarkable country has had upon the philosophy and science of the world, and from the additions it has made to the great stream of civilisation; which, after flowing through ages of antiquity, and fertilising the centuries through which it has passed, is even now, in its present fulness, still coloured with the earliest of the sources from which it sprung. Architecture and sculpture, the art of writing, and the use of paper, mathematics, chemistry, medicine, indeed we might add legislation, and almost every art which flourishes under a settled form of government, either took its rise in Egypt, or reached Europe through that country."

Before examining the Architecture of the Egyptians, it is necessary cursorily to notice those peculiarities of situation, climate, and habits of thought, from which it took its rise. Egypt being little more than a strip of country formed by the annual inundation of the Nile, in the midst of a sandy desert, bounded by rocks, was so far isolated and protected by the nature of its situation, as to be less subject to those perpetual invasions and inroads that form so prominent a part in the history of other countries. Egypt could only be attacked through narrow and difficult passes from Ethiopia, Syene, or Arabia Nabatæa; consequently, we find the same dynasty governing many hundred years. Manetho gives a list of native Thinite, Memphite, and other kings, including sixteen dynasties, extending over a period (if we may believe him)

of nearly 4,000 years before the invasion of the Shepherd Kings. During this time, the arts and sciences had made greater progress than in any other country. The soil and climate also had great influence in forming the character of the people. The continual struggle to preserve the valley of the Nile from the incroachment of the desert—or, as they expressed it, the perpetual conflict between the god Osiris (who annually arose from his bed in Philæ, to scatter blessings over the land) and the evil spirit Typhon—called forth all the energies of the people, and long preserved them from that enervating spirit of luxury and sloth, to which the downfall of so many nations may be traced. The peculiarities of their country, no doubt, also tended to make them the serious, devout people Herodotus describes. He says, "they are very religious, and surpass all men in the worship they render to the gods." They saw their land fertilised every year by the hand of Providence—the waters rushing down from an unknown source, and again, in due time, receding; they beheld the sun sinking, night after night, behind the unexplored and silent tracts of the great Lybian desert; and there arose within them an awful sense of the divine and mysterious, a haunting consciousness of the impotency of man compared with the *unmentionable One*,* to whom supreme homage was paid. The Nile was the great source of the prosperity of the country in another way; it was the longest inland navigation known to the ancients, and became the route by which the wealth of India was exchanged for that of Europe; thus pouring a continual stream of riches through the land of Egypt. So early were the advantages of the Nile navigation appreciated, that villages were thickly scattered over its valley, while the neighbouring countries of Arabia and Syria were only scantily peopled by a few herdsmen. The population of Egypt went on rapidly increasing under these favourable circumstances, and in the reign of Amasis II. (566 B.C.), it amounted to seven millions of inhabitants.

We do not possess many legends or traditions respecting ancient Egypt;—other nations boast of their poets and historians; but here they carved the names and deeds of their kings and heroes in stone, and painted the history of their private life on the walls of their tombs: so that if we have less of poetic fiction, we have a more certain basis of reality.

The name of This occurs as the first Egyptian city; then we have the names of numerous kings of Thebes and Memphis: of these we have no certain data; we only know that they carry us far up the stream of time; and when Abraham visited Egypt (about 1600 B.C.), he must have found the country already in a high state of civilisation. Next reigned the abhorred Hycsos, the Shepherd Kings—those "men of an ignoble race," as Manetho calls them; after their expulsion, a succession of native sovereigns extends over a period of 500 years. During this time, Thebes was the chief city, and Egypt surpassed every country in the known world in riches and power. 1400 B.C., Upper and Lower Egypt were united under Thothmosis II., and Queen Nitocris; and in the reign of Amnopth II. (1300 B.C.), Moses was educated in all the learning of the Egyptians. In the following century (1200 B.C.), we arrive at the era of Rameses the Great, the Augustan age of Egyptian history; the age in which native arts and architecture was brought to the greatest perfection. The following 500 years, from the time of Shishak, the conqueror of Rehoboam, the Thebaid sunk to the rank of a province, and Memphis once more became a capital city. The wealth and population of the people continued to increase,—but patriotism and virtue had declined. Instead of adding to the magnificent monuments of their predecessors, the monarchs now bestowed their riches in hiring Greek mercenaries to support their throne. It was in this period that the Greeks began to seek information from the learned Egyptians; and the illustrious names of Thales, Solon, and Pythagoras, occur amongst those of the travellers of that age. Mercenary aid can do little when native valour fails; and Egypt fell, under Cambyses (523 B.C.), never to rise again in her pristine glory and independence. The country passed successively under the yoke of Persians, Greeks, and Romans, though nominally still governed by independent princes. As long as native sovereigns remained to her, however (though only in name), the style of architecture altered but little: but soon after the reign of Cleopatra, it was merged, together with the kingdom, in that of all-conquering Rome.

In the general forms of their architecture, the Egyptians seem to have imitated the angularity of the bare rocks and drifted sand-heaps, and the long horizontal lines of the desert plain. Their building materials consisted almost entirely of brick and stone; the indigenous trees being principally palm, sycamore, and acacia (the former, deficient in strength and durability—the latter, too scarce to be used to any great extent in their buildings), served for household furniture, mummy-cases, &c. Wood was so highly prized by them, that cedar, ebony, and other rare woods, formed part of the tribute imposed on conquered nations; and East Indian mahogany was imported amongst the most valuable productions of that country.

Brick seems to have been the first material used, probably before the art of quarrying stone was known; it was afterwards employed in constructing walls of Inclosure, and in buildings where cheapness and expedition were greater considerations than durability. Egyptian bricks were generally crude, mixed with straw and dried in the sun; kiln-burnt bricks were occasionally used in foundations, quays, the raised terraces on which the towns were built, or in any situation where they would be exposed to frequent contact with water. The crude bricks were about 15 inches in length, 7 inches in breadth, and a little more than 5 inches in thickness: this simple material was found to be peculiarly suitable to that dry, hot climate, where rain scarcely ever falls; and were further recommended by the ease and rapidity with which they could be made. The brick-fields afforded abundant occupation for numerous labourers; and the demand was so great, and the trade so profitable, that the Egyptian government took it into their own hands, and considerably increased the revenue by this monopoly. In order to prevent unauthorised persons from engaging in this manufacture, a seal, containing the name of the king or some other privileged person, was stamped upon the bricks before they were dried: numerous bricks, thus stamped, have been found at Thebes and elsewhere. According to Vitruvius, crude bricks should only be manufactured in spring or autumn, in order that they may dry slowly; those which are made in the heat of summer speedily dry outside, while the inside remains moist: the brick thus becomes defective, and easily gives way. He further observes, that bricks ought to have been dried five years before they can be considered fit for use, and that their having been so should be certified by a magistrate. If these rules originated with the ancient Egyptians, it is probable that the stamp before mentioned may also have been a warrant of the solidity of the bricks.

The boundary rocks on each side of the valley of the Nile, afforded abundance of stone for every purpose. Basalt, syenite, and porphyry for obelisks and statues, and limestone and sandstone for building, is found from one end of Egypt to the other.

An ancient Egyptian city must have presented a very different appearance from those of any contemporary nation, from the absence of the surrounding walls, that form so striking a feature in Asiatic and ancient Greek towns,—the isolated position of the country precluding the necessity of this mode of protection. In order to check the incursions of the Arabs, a boundary wall of crude brick extended from Pelusium along the edge of the desert by Heliopolis as far as the Ethiopian frontier at Syene, a distance of about 187 Roman miles: many vestiges of this great work are still remaining. Walls of inclosure surrounded the temples; but these walls, though sometimes as much as 24 feet in thickness, appear to have been less for the purpose of defence than of marking the boundary of the sacred inclosure.

The monuments of Egypt may be divided into six kinds:—1st, Pyramids; 2nd, Those enormous piles adapted to the threefold purpose of temple, palace, and fortification; 3rd, Structural temples, fortified and unfortified; 4th, Temples, partly excavated, partly structural; 5th, Monolithic and excavated temples; and, 6th, Tombs.

The pyramids of Cochome are not only the most ancient monuments of Egypt, but probably the oldest in the world. Manetho ascribes them to Venephres, king of This, in the 1st dynasty. The great pyramids of Geezeh were built by Suphis, or Cheops, and his successor, Sensuphis, as it is supposed, about 1600 B.C. These enormous structures occupy each a square plot of about eleven acres: the largest is 728 feet on each side of the base, and about 500 feet in height. The pyramidal form seems to have obtained favour amongst all the nations of antiquity. We find pyramids in Assyria, in India, and among the remains of Central America. It has been suggested that the form may have originated from the old Mithratic worship, and have been symbolical of the rays of the sun. The pyramid may, however, have presented itself as the most enduring form, as well as the simplest in construction, enabling this ancient people to raise monuments on that gigantic scale after which they aspired; nor if we allow that whatever tends to create ideas of superior force and energy contains the elements of the sublime, can we deny this attribute to the pyramids and other marvellous works of the ancient Egyptians. He-

* It was considered impious by the Egyptians to name the Supreme Being.

rodotus informs us that King Cheops put a stop to all other works until the building of his great pyramid should be completed; 100,000 men were unceasingly employed, and relieved every three months by an equal number, and that twenty years were occupied in its erection; he also gives us an account of the quantity of radishes, onions, and garlic consumed by the workmen (probably their only wages); on these were expended 1600 talents of silver, or, in our money, about eighteenpence a-year for each workman. This information Herodotus gained from the hieroglyphic inscription that still existed on the side of the pyramid in his day. There is now no doubt that the pyramids were intended as sepulchres. Queen Nitocris erected the smallest of the three near Memphis, and cased it with red granite from Syene. In the valley of Saggarah, thirty pyramids still exist, and there are traces of many more.

Both in the plain and on the heights above Thebes, are many remains of small crude brick pyramids, in one of which is the most ancient arch yet discovered—its date is given as 1540 B.C. The Egyptians, constant and inflexible in all that bore upon religious forms, observed in the construction of their temples the same immutable rules: these edifices, therefore, only differ one from another in size and extent. The principal characteristics of Egyptian architecture are vastness, simplicity, and angularity; forming a style so stupendous, and so calm in its massive grandeur, that these monuments above all others have been able to defy the ravages of time, and still strike the beholder with admiration and wonder. Inability to combine solidity with lightness, probably produced the massive exterior walls, sloping from the base upwards; but while the exterior had always a pyramidal form, the interior wall was vertical,—thus giving a greater thickness at the base than towards the summit. Another peculiarity is the profusion of columns which would necessarily result from the mode of roofing, the roofs being formed by huge blocks of stone stretching from column to column, always perfectly flat, and without pediment: therefore, when halls of great size had to be roofed, it could only be done by placing rows of columns in the interior, to support the horizontal blocks,—a method that injured the effect, and greatly interfered with the space.

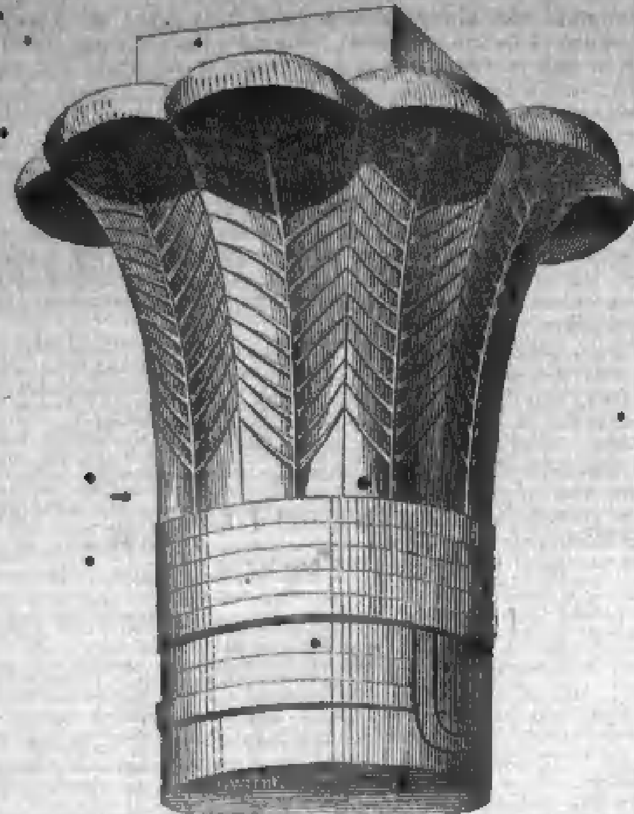
The great temples of Egypt were not like those of Greece and Rome—a complete structure composed of one order—but rather an assemblage of porticoes, courts, vestibules, galleries, and halls, united together within an inclosure: each one of these parts was generally independent of the rest, was ornamented by columns of a peculiar form, and in its dimensions had no reference to the other portion of the building. The sacred inclosure was surrounded by a wall (as before mentioned), and was planted with palms and flowering shrubs. From the entrance gateway to the first pylon was a paved avenue, called a dromos, ornamented with rows of sphinxes or colossi: from the first pylon we are led to another, and sometimes even to a third; these pylons were huge pyramidal towers in pairs, with a gateway between; these were the bulwarks and watchtowers. The entrance doors were elaborately decorated; and staircases were formed in the thickness of the gateway walls, leading to the flat roof of the tower; they ascended in a direct line, from one landing-place to the next, and each landing-place was lighted by small windows or loop-holes. The space between the pylons formed vast galleries or halls. After these we reach the pronaos, and sanctuary or adytum; frequently, also, there were chambers surrounding the adytum, serving as residences for those who had charge of the temple and the sacred animals. At the posticum there was sometimes another large hall, probably serving as a hall of justice; and Diodorus Siculus informs us that the sacred writings were kept in an apartment in the temple. The halls and vestibules were lighted from the top; the roof over the centre part was raised above what may be called the side aisles, the spaces between the necessary supporting blocks being left open, or filled-up by a stone grating,—thus producing a solemn twilight, which must have been both imposing and refreshing after the glare of the scorching sun and blinding sand. I must not omit to mention one great singularity of construction, which is, that the inner apartments of the temple regularly diminished in size: thus, the pronaos was smaller than the vestibule, and the adytum than the pronaos. The side walls gradually sloped inwards, the ascent of the ground was formed by shallow steps, and the descent of the roof concealed by massive transverse architraves; thus the sanctuary, to which the priests only were admitted, appeared to the worshippers not small, but distant. This plan is most strikingly apparent in the temple of Omboo.

The shafts of the columns are either polygonal or circular; it does not appear that the Egyptians had any fixed proportions. The columns were always massive, and those in the great hall at Karnac are 11 feet in diameter; owing to the buildings being so much choked up with sand, it is difficult to ascertain the exact height, but the loftiest columns (those of Luxor), probably do not exceed 56 feet. The polygonal columns are the most ancient; those of Beni-Hassan and Kalapshe may be of doubtful origin, though the shafts of the latter excavation have received a more undoubted Egyptian character from the stripe of hieroglyphics extending from base to capital in each shaft. The oldest purely Egyptian form resembles a bundle of reeds bound together with cords; the capital is formed by the bulging out of the reeds, as would naturally result from the pressure of a superincumbent weight; the shafts are compressed at the base, as if the reeds were more tightly bound.

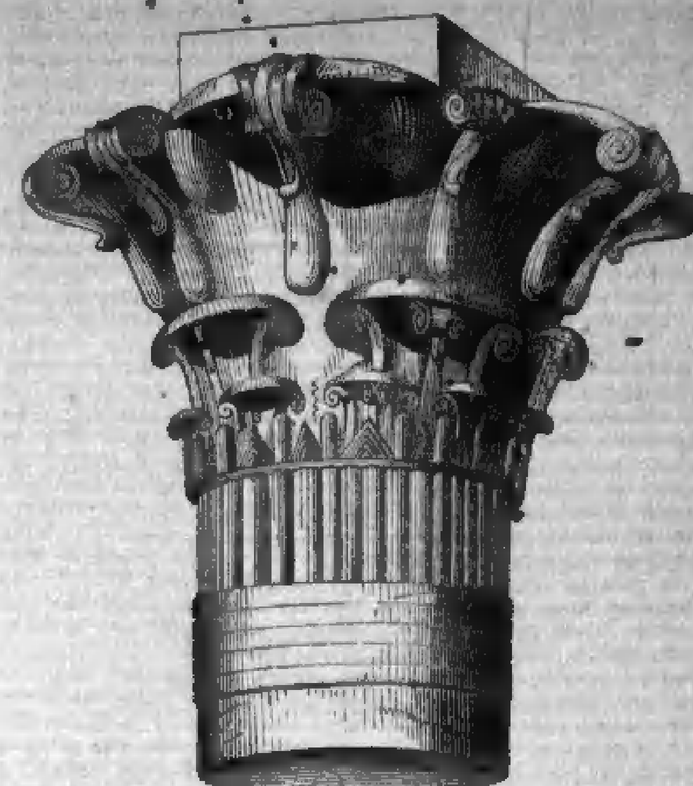
The capitals do not vary so much in form, as in ornament; they are generally vase-shaped, or present a graceful curve—perhaps imitated from the palm branch. These capitals are the first traces we discover of imitative taste, the decorations being exclusively copied from indigenous plants, and representing the delicate leaves and blossoms of the lotus, the palm, vine, or papyrus (as shown in the opposite page). Other capitals were surmounted by heads of the goddess Isis, supporting a miniature adytum, as at Dendarah and Philœ.

Isis Capital.

The capitals of the columns in a hall or gallery, though symmetrical in form, were frequently infinitely varied in ornament, as in the temples of Edfou, Esnèe, and Philœ. Though, on account of the accumulation of sand, the bases of the columns are no longer visible, it may be conjectured, from the narrow intercolumniations, that they either had none or stood upon a simple plinth, as in some of the excavations. The profile of the entablature is little varied; the general crowning member is a large bead and cavetto, as shown in the engraving of the pylon of Thebes. Sometimes the frieze is sculptured, sometimes plain, or carved with hieroglyphics.

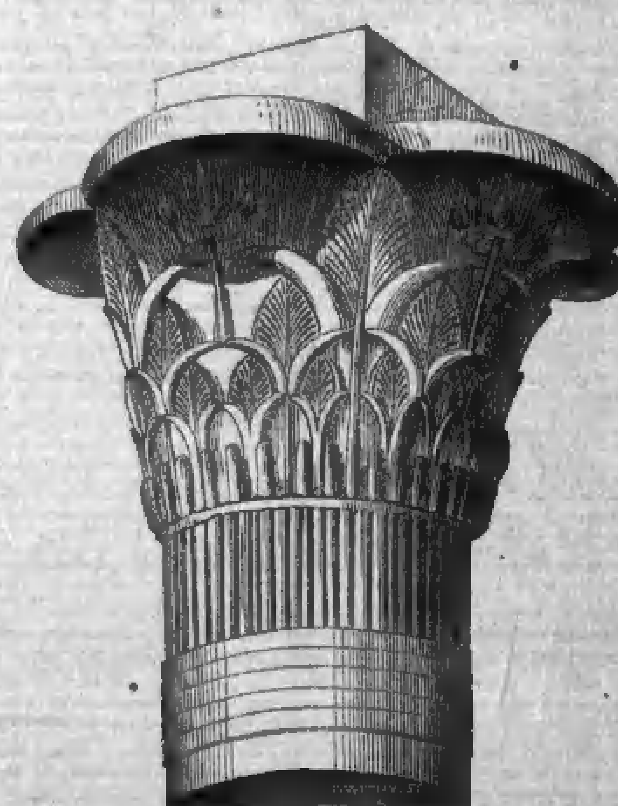


Palm Capital.



Lotus Capital.

Palm and Vine Capital.



Papyrus Capital.

The walls and roofs of the temples are frequently entirely covered with hieroglyphics and sacred symbols, carved in bas-relief and richly coloured. This mode of decoration was sometimes applied also to the exterior of the building, the pylons being covered with carving, as at Luxor. The adytum is the most elaborately ornamented; and here is found described the tutelary deity of the temple, the name of the founder, &c. The Egyptians seldom made use of ornament without a meaning: the winged globe, so constantly repeated above the doors and on the roofs, symbolised eternity or infinity; the triple rows of reeds on the

cavetto (something resembling the triglyph) separated the ovals containing the names of the kings, builders, or restorers of the temple. The sculptured frieze was frequently formed by rows of the sacred asp and globe: thus they appealed to the devotional feelings of the people, or taught them a history in every decoration. Occasionally, the shafts of the columns were merely coated with white stucco,—and, to our great surprise, we sometimes find even the beautiful granite of Syene treated in a similar manner.

When sandstone was employed, it was necessary to cover it with a smooth, unabsorbent composition before painting. In painting, red, blue, and green was the favourite combination; when black was used, yellow was always introduced as a contrast. The reds and yellows were ochres; the blue, metallic, prepared from copper; the black, lamp-black; and the white, finely-prepared gypsum or lime: these paints were mixed with water and a little gum, to render them more tenacious.*

The Egyptians were well acquainted with the manufacture of glass and enamel: a chamber in one of the pyramids of Saggarah is lined with blue porcelain slabs, like Dutch tiles.

That the Egyptians had a thorough knowledge of the art of masonry is evident—the stonework in the interior of the great pyramid of Geezeh has never been surpassed in any age. The shafts of the columns were sometimes carved out of one solid block; but when formed of sandstone, were built in courses varying in number according to the height of the column—Pococke counted seventeen courses in one column. More than one kind of cement was used by the Egyptians: the mortar employed in building the great pyramid was lime mixed with sand. Occasionally, the stones were fitted one to another without cement; and in some cases where they have become partially separated, wooden toggles are observed.

It is singular, that in a country where so little rain falls, the architects should have been so particular in fitting the stones that formed the roof; but so attentive were they to this, that besides carefully cementing them together, the interstices were covered with a piece of stone let into a groove of about eight inches in breadth, extending equally on each side of the line of junction.

I have already noticed the discovery of the arch in the brick pyramid near Thebes; but the most common kind of vault in Egypt was formed by layers of stone projecting one beyond another, and capped by a horizontal stone at the summit: the inverted steps were afterwards hollowed out. In one or two instances, the great stones forming the roof have been placed on the supporting columns edgeways, instead of on their face, so as to give a sufficient thickness to allow of their being hollowed out, and thus forming a vaulted ceiling.

Crio-Sphinx.

There seems to be some doubt as to whether the Sphinx is of Egyptian or Assyrian origin; it occupied the same position in both countries—at the entrance of the palace or temple; and in both countries expressed the same meaning, being typical of the most perfect union of physical and intellectual power. In Egypt, it was used as the symbol of the king or governing power. The Egyptian sphinx was of three kinds—the Andro-sphinx, or human-headed; the Crio-sphinx, or ram's-headed; and the Hieraco-sphinx, or hawk-headed: they were all represented with the body of a lion, and a small figure of the king was occasionally placed between the paws. The great sphinx near Memphis was carved out of the solid rock, in the reign of Thothmosis IV., about 1300 B.C.; according to Pliny, it measured 63 feet from the ground to the top of the head, was 143 feet in length, and the head round the forehead 102 feet in circumference. An adytum, with an altar for sacrifice, was placed under the chin, so that the worshippers walked up the avenue formed by its huge paws; and the smoke of the incense ascended to the nostrils of the monster.

In their sculpture, as well as their architecture, the Egyptians were restricted to the same original forms by religious rules; it is therefore difficult to judge whether, if such had not been the case, they would have been able to delineate the human figure correctly. We know they could give the idea of action, from the animated groups in the paintings on the tombs. Nevertheless, the Egyptian statues have an effect of calm grandeur, and a serenity and benevolence of aspect, that cannot fail to excite a feeling of veneration, as they sit with their hands placed straight on either knee, peacefully looking out into space, and smiling upon the centuries as they have rolled by; or stand with folded arms, bearing the flagellum, as the inflexible judges of human deeds.

Thebes contained two great palace-temples—El Karnac and Luxor; the palaces of Medinet-Aboo, and the Memnonium or Rameseum, besides other great buildings, as the temple of Dayr-el-Bahree, built by Queen Nitocris, and that called the tomb of Osymandyas, where stand the osirides, improperly called caryatides: it is worthy of remark that these osirides do not sustain the entablature, but are merely attached to the supporting pillars.

Osiride.

The most ancient building is the palace-temple of Karnac; it was the work of many successive kings, and is now the largest and perhaps the most splendid ruin in the world. The wall of the sacred inclosure would appear to have encompassed an entire city, rather than one edifice. This stupendous structure was founded by Osirtesen I., upwards of 1600 B.C. It was enlarged by Queen Nitocris, who set up the two great obelisks in the court, each

* The finely painted columns of Karnac, even now showing in their almost pristine beauty, were tinted in water colour.

92 feet in height. Thothmosis III. made several additions, which were carried on by his son, Amunothph II. (1321 B.C.), in whose reign the arts of painting and sculpture made rapid progress,—though in the columnar hall built by him at Karnac, with reversed cornices and capitals, we find a greater instance of caprice than of good taste. This palace-temple was enlarged and decorated by almost every succeeding monarch. To give an idea of the gigantic proportions of this edifice, it may be mentioned that the great hall of assembly is 329 feet in length, by 170 feet in breadth, and 65 feet in height, and containing 134 columns; the lintel of the doorway is formed of one sandstone block, 40 ft. 10 in. in length and 5 ft. 2 in. in depth and breadth. The walls of this enormous structure are 25 feet in thickness.

The neighbouring palace-temple of Luxor (Plate I.) was begun by Amunothph III. about 1300 B.C., and finished by Rameses the Great, nearly 100 years afterwards. Two beautiful obelisks, of red granite, bear his name, and give evidence by their hieroglyphics, cut two inches deep, of the wonderful skill of the Egyptians in sculpturing this hard material. This temple is only inferior in size to that of Karnac: the length of the colonnade leading to the court is 170 feet; then follows an area of 155 feet by 187 feet, surrounded by a peristyle, containing twelve columns on every side; this terminates in a covered portico, 57 feet by 111 feet, supported by thirty-two columns. A dromos (not less than a mile in length) of six hundred crio-sphinxes, raised on a causeway far above the level of the Nile, connected the palace-temples of Karnac and Luxor, and formed the main street in the eastern district of Thebes. Another great dromos—called in some papyri found at Thebes, the "Royal street"—crossed the city in a westerly direction, communicating with the opposite bank of the Nile by means of a ferry. The soil of the desert was paved with sandstone blocks, as a foundation for the dromos.

The palace sometimes called the Memnonium, but more properly the Rameseum, was built or completed by Rameses the Great; this building, and also the palace of Medinet-Aboo (built by Rameses III., 1100 B.C.), do not seem to have been used as temples, but probably united the citadel with the royal residence. The celebrated *Pair*, called the Memnon statues, measuring each 60 feet in height as they sit, guarded the entrance to the dromos of the Rameseum; the rest of the avenue was formed by numerous pairs of colossi, nearly as large, but whose fragments now strew the ground.

The city of Memphis has ceased to exist. The temple of Pthar, the residence of the sacred Apis, and all the other great buildings with which it was adorned, have been completely buried or destroyed. Diodorus Siculus informs us that with its suburbs Memphis had a circuit of upwards of 16 miles: but now it presents nothing to the eye of the traveller but a sandy plain, an overthrown colossus of Rameses II., a few fragments of granite, and some foundations. How have the mighty fallen!

Amongst the numerous temples erected in Egypt, none are more interesting than those adorning the sacred island of Philæ. This island rises majestically with its monuments in the midst of the river Nile, above the first cataract, and was believed to be the burial-place of Osiris: "By him who sleeps in Philæ," was the Egyptians most solemn oath. The island is entirely surrounded by a wall, marking it as a sacred inclosure, and must have been as enchanting from the beauty of its site, as imposing from the magnificence of the temples with which it was covered. Numerous pylons, porticoes, columns, and obelisks yet remain, and the hypæthral temple, or bed of Pharoah (as it is sometimes called), is but little injured by time. Elegant and lofty columns, with capitals sculptured in various forms, support the entablature; two opposite doors, with broad imposts in the form of pilasters, afford ingress and egress; and the sides of the building, instead of being entirely inclosed, have the intercolumniations filled in with low walls or panels, to about half the height of the columns; these panels are finished with the usual bead-and-cavetto moulding. All the buildings on the island are covered with sculpture and painting, even to the shafts of the columns.

The Ptolemaic temples of Edfou and Esnée deserve notice, from the exquisite beauty and finish of the carving and stonework. The former also possessed great strength as a fortification; the lofty portico (like that of Denderah) is much higher than the body of the temple, and the narrow gateway of the pylon is the only opening in its massive walls. The city of Apollinopolis, where this splendid structure was erected, was situated on an eminence overlooking the river and the valley,—the great pylon was doubtless intended to command the whole.

Many of the smaller temples, or those in the neighbourhood of larger fortified temples, were without pylons, the principal entrance being through the portico; several have a peristyle, as those of Elephantine, Ermopolis, and others.

Of those temples partly structural and partly excavated, like that of Dahr-el-Bahree, it is needless to say more than that the adytum was carved out of the rock, while the vestibule and pylon were built.

We now come to the wonderful monolithic and excavated temples. There are monolithic temples both at Buto and Saïs. The temple, or rather adytum, or shrine, at Saïs, was intended by Amasis to adorn his great temple in that city. It is said to be a 60 ft. cube, carved out of one block of granite. It took 2,000 men three years to convey it from the quarries of Esouan, a distance of 700 miles. It stands in front of the temple.* There is a tradition, that as the men were about to move it onwards to its intended destination *within* the temple, the engineer heaved a deep sigh, which so affected the king with the idea of weariness, that he commanded the work to cease: and the shrine remains as it was then left to this day.

It has been supposed that the temples and tombs carved out of the rock were the earliest attempts of the architect; but this seems a mistake, so far as either Egypt or India is concerned. These excavations afford a clear proof of their derivation from structures, in the architrave reaching from column to column—taken from the beam supporting the roof: this feature is totally at variance with the nature of a cave; and no further evidence can be necessary, as the imitation must be subsequent to the thing imitated.

The temple of Aboo-Simbel is in Nubia, on the west bank of the Nile, and belonged, with so many other stupendous works, to the reign of Rameses the Great. It was discovered by Burckhardt in 1813, and afterwards further explored by Belzoni. It is hewn, together with its colossi, in the hard gritstone rock. The four colossal figures in front (only one of which has been entirely cleared of sand) represent the great founder, Rameses; they measure each 70 feet in height, and 25 ft. 4 in. across the shoulders; the face is 7 feet in length, and the ears 3 ft. 6 in. On the front of the thrones, female figures are carved, supposed to be intended for his wife and children. During the execution of these colossi, where defects in the stone were discovered, they were filled-up with mud and straw moulded to the required form. The adytum terminates 200 feet from the entrance, and there four more colossal figures are seated, side by side, in the dim light.

Another smaller excavated temple exists in the immediate neighbourhood, dedicated to the goddess Athor: space will not allow me to enter upon the description of this, Garf-Hoseyn, and other wonderful excavations with which Egypt abounds.

The importance the Egyptians attached to the preservation of the body after death, probably first induced them to seek a place of sepulchre in the neighbouring rock, where security would be found against damp and other destroying influences. As these sepulchres increased in number, as year by year the population of the dead more and more exceeded that of the living, the inhabitants of the cities below would be led to think of the brevity of mortal existence, and would be impressed with the necessity of preparing a permanent home in the everlasting rock, against the time when they should be called to leave their transitory abode in the Nile valley. It was the profitable business of the priests to prepare these tombs; they frequently excavated them on speculation, selling them at a high price to those who had not the means of commencing a sepulchre early in life, as was the custom among the wealthy. The priests, therefore, took advantage of the natural feelings of the people, and in every way fostered and encouraged their passion for expensive and elaborate tomb decoration.

Wherever an Egyptian city arose, we find a necropolis in the neighbouring Lybian or Arabian mountains. These tombs consist of vestibules, halls, galleries, and chambers, differing in number and extent according to the wealth of the occupant, whose name, rank, and mode of life, was illustrated on the walls; they had all square doorways, sometimes plain, sometimes with a richly ornamented façade. Frequently the entrance to the tomb was closed with solid masonry, but in others the outer chamber appears to have been used as a private chapel; and many had gardens planted in front, where the flowers were tended by the hand of some faithful mourner.

Between three and four miles from the river, in the immediate vicinity of Thebes, is a tortuous path, formed by a natural cleft in

the rock: this leads to the celebrated valley of Biban-el-Moluk —the valley of the Tombs, where the great Theban kings have found their last resting-place. Many of these tombs remain unexplored, but those which have been opened are sufficient to attest the wonderful labour and skill, and the vast expenditure, lavished on their preparation and adornment.

The tomb of Amunothph III. is one of the most extensive of the royal sepulchres: it descends into the solid rock 320 feet in horizontal length, and its perpendicular depth to the place where it is closed by the fallen rock is 180 feet. In some of the inferior chambers it is probable members of the king's household may have been buried.

Another richly decorated tomb is that of Oimeneptha, opened by Belzoni: in a small vaulted chamber beyond the third and largest hall was discovered the alabaster sarcophagus now in Sir J. Soane's museum.

In the reign of Osirtesen I. (about 1650 B.C.), were excavated the beautiful grottoes of Beni-Hassan, near Antinöopolis, the polygonal columns of which have been supposed to be the original of the Doric; these columns are 3 ft. 4 in. in diameter, 16 ft. 8½ in. in height, and have 16 faces, each about 8 inches in width; these faces are slightly grooved to the depth of about ¼-inch, thus suggesting the idea of fluting: a simple abacus forms the capital. Two columns supporting an entablature projecting from the rock, out of which it has been carved, completes the façade. Upon the architrave a sort of dentel is sculptured; the cornice is too much broken away to allow of a decision as to whether it had the Egyptian or Doric character. A beautifully-proportioned doorway forms the entrance, the imposts and lintel of which are covered with carved hieroglyphics. On the lintel the following words have been deciphered: "A good house, food, and drink—bread, geese, cattle, perfumes, as offerings to the General, Nahride Nevothph, son of Dgiok." The principal chamber of the tomb is of a square form,

Beni-Hassan.

about 30 feet in length and breadth. Two longitudinal architraves, each supported by two columns, similar to those on the exterior, divide the ceiling into three parts, each division being vaulted and decorated with stars on a blue ground: the basement and architraves are covered with hieroglyphics, coloured green on a red ground; and the walls are adorned with paintings representing the daily habits of Egyptian life, and, it is to be supposed, of Nahride Nevothph in particular. The fancy of the artist was allowed greater play in the tombs than in the temple, and we frequently find ornamental patterns very similar to those in use up to the present day. There are several other grottoes at Beni-Hassan, in one of which are reed-shaped columns; another has polygonal columns with plain sides.

Although the Egyptians expended so much money and labour in the preparation of their tombs, they were by no means negligent in providing for the comfort and luxury of their houses. From the amusingly detailed drawings they have left us, we have acquired a closer insight into the homes and manner of life of the Egyptians than of those of any other ancient nation. Diodorus Siculus tells us that the Egyptians originally built their houses of reeds. This may probably have been the case; but as brick-making was so early an invention, the reed houses were mostly soon confined to the lowest classes; and this may be the reason we find no representations of them on the tombs. The houses there delineated are of crude brick, as are found in the ruins of the Alabastron and elsewhere, and were covered with stucco.

One of the houses painted on a Theban tomb represents a square inclosure, to which ingress is gained by doors on opposite sides; the door to the left leads into a garden, where is a vine-arbour, and four trees. Beyond the garden is a courtyard, where, in several tiers, bread and meat, &c. is set out in the air in vases. On the right of this court is a gallery or passage, with a large window: then follows the house, with the entrance-door to the right. This house consists of two stories; two rectangular windows are seen with light and elegant imposts and architrave, variously ornamented and painted; the window-shutters are perforated, so as to admit the air and moderate the light. Above the second story is a terrace, with a roof supported by columns. A cornice runs along the side of the house as far as the entrance-gate, supported at each end by a pillar in the form of a stalk of the papyrus, with a square abacus.

Another house is represented in the midst of a beautiful pleasure garden; by the side of one of the walls flows the river, shaded by a row of tall trees. From this walk an alley leads to the entrance gate; from this an avenue of trees conducts to a smaller gate, opening to the vine-arbour. The garden is laid out in walks or alleys, some of which lead to tanks of water surrounded by little verdant plots, on which vases containing plants are placed; in the tanks the lotus is growing and water-birds are disporting themselves. Here are also two small pavilions or summer-houses, surrounded by a balustrade. At the end of the garden, behind the vine-arbour, stands the house, which is entered by two doors; two elegantly decorated windows give light to the ground-floor; above are three stories, the upper one finished with a cornice, on which is placed three vases containing papyrus plants. The columns at the entrance-door were on festive occasions ornamented with ribands and banners: the name of the person to whom the house belonged was painted on the lintel or imposts of the door.

The rooms were usually arranged round an open court, or on either side a long passage; and in the court was generally a mandara, or receiving room for visitors. The ground-floor was chiefly used for store-rooms. The walls of the rooms were stuccoed inside and out, and variously ornamented with painted devices. The doors were frequently stained to imitate rare woods; they were sometimes single, sometimes folding, turning on metal pins and secured within by a bar or bolts of bronze. The floors of the rooms were either of stone or composition; the roofs formed with rafters of the date-tree, laid close together, or apart when transverse layers of palm branches or planks were added. Occasionally the ceilings were of crude bricks and vaulted. Sometimes, instead of a covered terrace, the house was surmounted by a *mulquf*, or wind conductor, such as is seen at Cairo at the present day. In some instances, part of the house was raised above the terrace as a tower, and was ornamented with battlements, in the form of half-shields. Each house had its granary, sometimes separated from it by an avenue of trees. We may judge how much trees were valued in that country, by the careful manner in which they were tended: each tree was surrounded by a low wall, to protect it from the cattle or other injury, with holes bored to admit the air.

The streets in the towns seem to have been regularly laid out, without the mixture of large houses and hovels, so usual in eastern cities. As is generally the case in hot climates, the streets were narrow, only the principal ones admitting the passage of a chariot. The houses of the lower classes were connected together, so as to form the continuous sides of the street; some of these small houses consisted merely of a court, and three or four store-rooms on the ground-floor,—with a single chamber above, to which a flight of steps led from the court. The upper chamber was so small and inconvenient, that it could scarcely be used for anything but an occasional shelter from the heat of the sun, or a place from whence the master could overlook his household; as Sir Gardiner Wilkinson remarks, it calls to mind the proverb: "It is better to dwell in a corner of the house-top, than with a brawling woman in a wide house." The shops were either open stalls similar to those in an eastern bazaar, or else mere booths in the public thoroughfares. The Egyptians possessed also extensive villas with orchards, vineyards, and pleasure grounds. Some of the larger country mansions had pylons and obelisks at the entrance, like small temples.

In contemplating the vast structures raised by the ancient Egyp-

tians, we are at a loss to conceive how a people comparatively ignorant of the mechanical arts could have achieved such gigantic works. Though it is probable they had contrivances either unknown to us, or now considered as comparatively new inventions, yet from all we can learn from written history, or from their own sculptured records, it seems that they depended more upon time and manual labour, than upon those arts by which modern undertakings are so much facilitated. It is remarkable that while the Egyptians have left us such minute and copious details respecting their customs, trades, and manufactures, any notice of engineering works is extremely rare: this may probably have been owing to its having been under the direction of the priests, and kept as a mystery. In a bas-relief we see a seated colossus which is being moved; ropes are fastened to every part of the figure, and are then gathered into one knot, to make the pull equal; and numerous strings of men are hauling it, the engineer standing on the knees of the figure, directing their movements. In another bas-relief we see oxen employed in drawing a stone.

We are told that in building the pyramids, in order to bring the stone from the boats on the Nile, a causeway was formed, 1000 yards long and 50 feet high, and this was probably raised as each successive course of stones was added,—so that each stone was rolled up this inclined plane to its place. If a huge stone was to be placed on the top of a wall, it was dragged up an inclined plane of sand to its destination. We have an account of an obelisk 80 cubits in height, that had been made in the reign of King Nectanebo; this the king Ptolemy Philadelphus wished to set up in Alexandria, in honour of his sister. To this effect, Satyrus, the architect, is said to have dug a canal to it as it lay on the ground, and to have placed under it two heavily-laden barges. As the barges were unloaded they floated higher, and thus raised the obelisk from the ground. Unfortunately, we are not informed how he afterwards proceeded to set it up in its destined position.

In quarrying stone, wedges were used, either of metal struck with a mallet, or of dry wood, which, when moistened, split the stone. We have no reason to suppose that free labour was *not* employed, but we know that criminals and prisoners of war were sent to work in the gold mines; and those guilty of misdemeanour may also have expatiated their fault in the quarries. There exists an inscription at the quarries of Gertassy, in Nubia, "I have now dragged 110 stones for the building of Isis at Philæ," which would seem to indicate a penance performed.

The Egyptians must have been well versed in land surveying, levelling, and various branches of geometry, as well as in many operations requiring mathematical science. That they were early skilled in forging metals and polishing stones, their works remain to prove; the art of gilding was known in the reign of Osirtesen I. (1650 B.C.) We have no record of the discovery of the art of manufacturing steel; and from the speedy decomposition of iron and steel, few tools can be expected to remain; but we cannot examine the deep and sharp cutting of the Egyptian hieroglyphics, and suppose that instruments of any softer material can have been used. The cuttings may have been sharpened up with emery, which was within their reach in the islands of the Archipelago.

That the Egyptians were skilful engineers, as well as architects, we have abundant proof. The dykes directing the arbitrary overflow of the Nile, served also as raised roads—the only mode of land communication during the inundation: they followed a tortuous path, visiting the various towns and villages on their way. A canal was cut from the Nile to the Gulf of Suez, in the time of Rameses the Great; at the mouth of this canal were sluices to regulate the supply of water. And as early as the reign of Thothmosis III., between 1300 and 1400 B.C., the Lake Mœris was formed, which regulated the overflow of the Nile in that part of the country, and by its means thousands of acres were irrigated, and thus brought into cultivation.

I must now conclude this sketch of the Architecture of the Egyptians: space and time will not allow of more, or volumes might be written on the subject. If I have said enough to show how high a place the Egyptians occupied among ancient nations, and to how great an extent civilisation had been carried at that remote period, I must remain satisfied—referring the student for further information respecting this interesting people, to the valuable works of Sir Gardiner Wilkinson, Professor Rosellini, MM. Denon, Champollion, and others.

LIST OF AUTHORITIES.

Wilkinson's Manners and Customs of the Ancient Egyptians.
Wilkinson's Thebes.
Sharpe's History of Egypt.
Rosellini, Monumenti d'Egitto.
Canina, Architettura Antica.
Laborde's Illustrations.
Roberts's Egypt.
Quatremère de Quincy. Encyclopédie Méthodique.
Miss Martineau's Egypt and the Holy Land.

*** The Panorama of the Nile at present exhibiting at the Egyptian Hall, Piccadilly, will afford the student in Egyptian architecture a very clear idea of the stupendous works of antiquity, and well repay a visit. Of course it is to be supposed the student avails himself of the Egyptian Gallery in the British Museum, and of the Soane Museum.

DESCRIPTION OF THE COFFERDAM AT THE GREAT GRIMSBY DOCKS.

Engineer: JAMES M. RENDEL, Esq.

(*With an Engraving, Plate* II.)

The position occupied by this cofferdam is one of very great exposure. It is open immediately in front and on the eastward to an estuary 7 miles in width, and on the north-west to the whole current of the Humber for a reach of 20 miles, with a 25 feet rise of tide against it on the outside, and an excavated depth of 11 feet below low water immediately behind it, as necessary for laying the foundations of the locks. Moreover, the Humber is frequently exposed to violent storms; and finally, this cofferdam, unlike most structures of its class, must depend entirely on its own strength and form of construction for the requisite stability, as there is nothing in its whole length of 1,500 feet from which to derive support of any kind. It is therefore the more satisfactory to record that the work was completely carried out without any necessity arising for altering a single feature of the design in the course of its execution.

The plan of the cofferdam is a compound curve formed of two circular arcs, with a straight return on the west side; and the versed sine of the curved portion is (200 feet, or) $\frac{1}{5}$th of the span nearly. The dam consists of a triple line of whole timber sheet-piling, of which the outside row is battered half an inch per foot; and the other two rows are upright. The sheeting was all driven between gauge or bay piles, placed 10 feet apart; and the three last-driven piles of each bay were accurately sawn to a taper, in opposite directions, so as to wedge the remaining piles of the bay closely together. The average length of the piles in the first row is 35 feet; and that of the other two 45 feet. They are all driven to enter a bed of hard clay; but the ground through which they pass before reaching this bed is of a weak and silty character. The width between the first two rows of piling is 7 feet; and that between the centre and back row is 6 feet. The puddle clay occupying these spaces was mixed with one-fourth of small broken chalk stone for the first 5 feet in height, and perfect consolidation was insured by tipping the puddle throughout, from earth waggons on the top of the dam; single barrow-loads, even from that height, being entirely forbidden. The front and back rows of piling are secured by five tiers of whole timber double-walings; but in the centre row, the three lowest tiers of waling have been replaced by bands of wrought-iron, 6 inches broad by 1 inch thick, which are keyed together in lengths of 19 feet, and form a continuous tie on either side of the piling from one extremity of the dam to the other. In this capacity alone they are very serviceable; but the principal object of the arrangement is to insure an uninterrupted surface over the face of the sheet-piling on both sides, in order that the puddle may at all times be closely packed against it without leaving any of those voids which are inseparable from the use of ordinary timber walings in such situations, and serve as channels for any water that may pass along the through-bolts.

Another precaution against the admission of the water was observed in the arrangement of the long bolts, which were all distributed in such a manner as to break joint, never entirely passing through the dam, but in every case terminating at the outer row of piling, being screwed up against the wrought-iron plating, between which and the face of the piles a washer of vulcanised india-rubber was introduced. The long bolts are $2\frac{1}{4}$ inches in diameter at the lowest tier of walings, diminishing upwards to $1\frac{3}{4}$ inches.

It is, however, in the method of giving interior support to the structure that the greatest constructive excellence and originality

of design will be found to exist. In place of the rows of single piles driven at a distance from a dam to which struts and braces are usually carried back, here are introduced buttresses or counterforts, consisting of close-driven rows of whole timber sheet-piling, 18 feet in depth, which spring immediately from the back row of the main pile sheeting, and occur at intervals of 25 feet throughout the work. The counterforts are strengthened by tiers of walings, corresponding with those in the inner row of the dam, and connected with them by strong wrought-iron angle-plates or knees, as well as by horizontal diagonal struts of whole timber, abutting in cast-iron dove-tailed sockets. By this arrangement, those portions of the dam included between the counterforts derive the full benefit of the strength of the latter, so that the whole structure may be said to stand virtually on a base equal to 32 feet, or the width of the dam plus the depth of the counterfort.

It is almost impossible to overrate the success which has attended this form of construction, for nothing can be more satisfactory than the manner in which the cofferdam has resisted the daily pressure of the water for the fourteen months since its construction, as well as the violence of several severe storms to which it has been exposed during that period. In order, however, to test its stability with the greatest degree of accuracy, the following arrangement was adopted:—Opposite to every fourth counterfort, at some distance from it, was driven a single pile, supporting a horizontal arm or index, fixed at the level of high-water spring tides; and of which, the extremity, graduated to parts of an inch, rested against the counterfort without being attached to it, so that any motion of the latter might be observed and measured on the graduated scale. The result of these observations was such as to inspire perfect confidence in the stability of the work; for under the pressure of high-water spring tides, the deflection at that level does not exceed half-an-inch. So great is the resisting power of the dam, that even in severe storms the blows of the waves against it are scarcely to be felt.

November 26th, 1849. ADAM SMITH.

FRENCH EXPOSITION IN LONDON.

If there were any doubt before as to the public mind being decidedly in favour of exhibitions of arts and manufactures, there can be none now. Events of late have given abundant evidence of this determined inclination; and the French Exposition in George-street, Hanover-square, very well finishes the year 1849, and is a good step in the progress towards 1851.

We have very lately shown the reasons why a great exhibition there is of less urgency than in France, and we will only remind our readers that in France, or in Prussia, the public being less mechanical, there is a greater attraction in such an exhibition; and manufacturers elsewhere being less advanced, it was the more needful they should be brought forward in such a way, and receive every encouragement from the government and the public. Even Portugal has her exhibition of arts and manufactures; and throughout Europe, every energy of the government is strained to foster the slightest branches of industry. In England, our very prosperity makes us heedless, perhaps neglectful; and the most glorious inventions are unrewarded by the government, and their authors left to the mercies of pirates and lawyers for the chance of a subsistence from their labours. With the riches of manufacturing genius displayed in our great streets, there was no more call on our government to set up an exhibition, than to form a national workshop for supplying the population with wooden shoes.

For the want of such an institution some excuse may be pleaded; but there can be none that Watt, Trevithick, Wedgewood, Cartwright, and Stephenson, went down to the grave without sharing in the honours at the disposal of the executive. With a public triumph awarded to industry in 1851, an occasion may perhaps be taken to consider the claims of inventors. Some share in public honours and rewards may perhaps be given to them; some relief from the heavy patent-tax be awarded; some more rational tribunal than one composed of lawyers be instituted for their protection; and some facility be granted for the operations of capital in their behalf. Statues for the dead a grateful posterity may bestow; but bread for the living is not too much to ask of the present generation.

The institution of a National Exhibition of Arts and Manufactures by the French in the time of the great revolution, is sufficiently known; but it is not so easy to trace the progress of like institutions among ourselves. The establishment of the Society of Arts, above a hundred years ago, led to systematic, though restricted, exertions for the development of industry in this country; but their encouragement of inventions and discoveries, no less than their museum of models, was on too small a scale to effect any great good, and in later times it was very partial in its operation. Although separate exhibitions of individual inventions had been from time to time set up in London, we believe the first practical attempt to organise an exhibition of the industrial arts was about the year 1832, by Mr. Charles Payne. This exhibition was held in the old King's Mews, before that building was pulled down to make way for the National Gallery. After a very limited existence, the exhibition resulted in the establishment, by Mr. Charles Payne, of the Royal Adelaide Gallery for the Advancement of Science; and afterwards, of the Polytechnic Institution, which was organised on a still larger scale, and has been more successful in its operation.

Elsewhere, one who had rendered such considerable service to the public would not have been forgotten in the disposal of patronage; and Mr. Payne is, besides, the author of useful inventions for preserving meat and preparing timber, with which it is almost needless to say he has been left to struggle on without a help from public departments, and with all the discouragement incident in this country to those who prosecute useful undertakings. Certainly it was no mean service to establish a museum of economical productions, with working models of new machines, a course of lectures on mechanical inventions, and a laboratory and school of chemistry. The Polytechnic Institution, we have no hesitation in saying, has had a large share in bringing about the present favourable state of public feeling, and in the establishment of many valuable institutions.

The movement for free museums, twelve years ago, led to better arrangements at Woolwich and the other dockyards, as museums of the mechanical arts. The establishment, at the same time, of schools of design throughout the country, was a successful measure for the promotion of decorated manufactures. These schools have likewise held their yearly exhibitions of drawings and designs.

When the Royal Botanic Gardens were formed in the Regent's Park, a museum and exhibitions of economic botany were proposed; but little more has been done than to give the impulse to the government gardens at Kew, where a good beginning has been made of a museum. The Museum of Economic Geology is more advanced, but there is still an opening for a Museum of Economic Zoology. The Botanical and Zoological Gardens are open freely to students of the Royal Academy and Schools of Design; but whoever looks at our designs and compares them with those of the French as shown in Paris, or in London, will see how much we are behind in the study of natural history to what the French are. Indeed, the main strength of their designs is in their intimate acquaintance with nature; whereas, our students are still copying from drawings or casts from the antique.

The operations of the Mechanical Section of the British Association, and of the exhibitions and model yards of the Royal Agricultural Association, have resulted in yearly exhibitions, on a limited scale, of economical productions, which have made known the resources of many localities. The branch agricultural associations have extended the influence of such exhibitions.

The exhibitions by the Society of Arts, in the last few years, of objects of ornamental manufacture, should not be left out of sight in this enumeration.

Provincial exhibitions, as that at Birmingham and those for the benefit of mechanics' institutions have, some of them, been on a considerable scale.

Thus, besides the influence of the press, in urging the example of France, Flanders, Dutchland, and the Mechanics' Fairs of the United States, the public mind has been gradually prepared for a great national exhibition, and all the elements of it have been slowly organised. One reason for which we have given this sketch is to show that, so far from the exhibition of 1851 being a rash or doubtful venture, it has every element of success, and that nothing is wanted but a careful and honest administration. It is new, as a whole, but not in its parts; it has been rehearsed piecemeal, and is ready for the stage. The first Paris Exposition, restricted as was its organisation, was an experiment much more difficult, and much more doubtful.

In all our colonies, exhibitions similar to those already described exert a like influence, and are equally promotive of effective arrangements.

If, therefore, we look at the machinery we have now in operation, we may feel confident that all will work well; and we have in

our local institutions, and in the familiarity of every district with these exhibitions, the means of surpassing any foreign effort. If any one comes to consider the number of our Societies, and the large sums yearly disbursed by them, he will feel little doubt of our resources.

Agricultural institutions descend from national associations to county and district societies; from these to agricultural clubs and cattle clubs.

Horticultural and floral exhibitions are held in every town. In London alone, 3,000*l.* are yearly given in prizes.

The migratory sections of the British Association, the scientific conversaziones, the Polytechnic associations, and the local exhibitions, afford yearly displays of mechanical inventions.

The exhibitions of the Society of Arts, and those of the Schools of Design, are rallying points for the designers.

In 1851, these are to be brought together, and nothing but gross mismanagement can afford a chance for failure. At any rate, we have invited the world to a competition in this its metropolis; we have thrown down the gauntlet, and we must not be beaten on our own ground and at our own weapons.

The French Exposition is a kind of advanced guard of our rivals, by which we may in some degree take measure of their strength. Within the walls of exhibition rooms—though those in George-street, Hanover-square, are large—it is not easy to give a complete illustration of the great Paris Exposition; nevertheless, the French Exposition constitutes in itself a fine exhibition, and affords no mean idea of the resources of our 'yond-Channel neighbours. Brought together on the suggestion and by the exertions of M. Sallandrouze de Lamornaix, it necessarily partakes much of the character of a private undertaking, and to some extent of a private speculation.

Monsieur Sallandrouze holds a high position in connection with the industrial interests of France, being the director of the great national manufacture of tapestry, and a member of the General Council of Manufactures, formerly a deputy, and in 1839, 1844, and 1849, one of the central jury or commission for the National Exposition. Many of the exhibitors held back from sending their productions, from doubts of the results of the Exposition, from jealousy of the proposer, or of the English; and many of those who sent did so from motives of speculation, in the hopes of making a sale of their goods. It is, therefore, as much a bazaar as an exhibition: but in either case M. Sallandrouze has achieved no mean success.

Machinery and the heavier productions have a very small share in the collection; neither have the coarser but more important manufactures more than a nominal representation, so that there is little to gratify technical interest; but it is as a demonstration of Parisian artistic skill, as a display of objects of luxury, that this Exposition remains as yet without an equal in England. This is the better for us; for our cottons and our iron we do not fear; but it is in articles of taste that we are behindhand, and for which we have the struggle to make; therefore we again thank M. Sallandrouze for this Exposition. Taken altogether, the tapestry, the silks, the porcelain, the glass, the bronzes, the cabinet-work, the knick-knackery, present a gorgeous display of cultivated taste, which the English public will see with surprise.

These things are not, however, to be seen and wondered at, and never again thought of, but as sights which have been; they must be considered and canvassed, and some profit be drawn from the lesson,—for this Exposition is suggestive of many striking thoughts. Why is it that France, which is neither so wealthy a land, nor has so wealthy an aristocracy, is able to beat us in these attributes of wealth? Have we the power of struggling with her for the mastery, or have we not—and is it worth our while?

To our mind, there is nothing disheartening in these considerations, but every ground of encouragement. Our army, it must be remembered, has not yet been brought together on the field; and when we look at that of our rivals, and acknowledge we have not yet seen a force so imposing, we must not give up hope for ourselves, but institute, so far as we can, a comparison of the details, which admit of it. "Have we as good a staff—as good engineers, as good artillery, infantry, cavalry, and train?" If we can answer "Yes" in each case—or if we can answer that though such an arm is worse, another is better—then we have no need to fear the result; and this, it strikes us, is what ought to be done here—to examine each branch, and then to review the whole. If this be done, those of our readers who know the resources of the country, will feel more confidence for 1851.

Tapestry we give up, for it is a government fancy in France, a "specialty," as are the great productions of Sèvres; and France must have the glory of these, as Rome of mosaics, Russia of grenadiers, and England of first-rates.

As to the porcelain and glass, putting the Sèvres demonstrations aside, we do not consider we are at all inferior to the French. In looking carefully at the invention, shape, colour, details, and finish, there is not that perfection on the part of the French which should reduce us to despair; but on the contrary, some very strong reasons for measuring weapons with them. There is to our seeming a purer taste in shape in England, and a richer taste in colour. We do not believe that in any branch of the arts, high or low, the French are our masters on these two heads. The French government have spent enormous sums at Sèvres, but our outward trade in earthenware is a much better stimulant. In porcelain, and in glass, we can make as good masterpieces; while the state of these manufactures is with ourselves much more healthy than in France, or any other country.

Our weavers can produce those specimens of silk which are the boast of the Lyons looms, but we are inferior in design in the general trade, because we have not reached the same height of cultivation. Spitalfields and Manchester will make a show in 1851; but this is not the test of a healthy condition. Our manufacturers, pattern drawers, weavers, buyers (as the *Art-Journal* well shows), mercers, and public, are not so well trained as in France. We want more and better schools of design, more picture galleries, and above all, more public botanic gardens. A free botanic garden in Victoria Park, and another at Manchester, will do more for Spitalfields and Manchester than almost any measure which can be proposed. Under decent management, these two botanic gardens could be established and upheld at a very moderate expense.

In the case of the Victoria Park, the twenty acres of land, which is the chief outlay, is already provided. Say, for laying-out paths 1,000*l.* If no show conservatory is tried, 5,000*l.* will make a good provision of hothouses and greenhouses. A curator can be had for 200*l.* a-year and a house. Gardeners are very cheap even in London—fourteen shillings each a-week for twelve men, will provide a sufficient establishment; for this 450*l.*; for materials, plants, coals, and other stock, 350*l.* a-year. Say 8,000*l.* for establishing the garden, greenhouses, and dwellings, and 1,000*l.* a-year for keeping it up. The 8,000*l.* might be got by public subscription; and the 1,000*l.* be raised by a rate or additional ground rent on the houses benefitted by Victoria Park.

Something of this kind must be done, for the establishments of London as now organised are inefficient. Kew is too far off; Chelsea, although admission is freely granted, is small, and a physic garden; Kensington and St. James's Park present little more than an arboretum. The Horticultural Gardens at Chiswick are too far off. The Royal Botanic Gardens in the Regent's Park are only accessible to artists, and not to the public. The Zoological Gardens are more accessible, but even sixpence is too much for poor weavers. The gardens of the Messrs. Loddige, and other nurserymen, cannot be looked upon as available to the public. The Ornithological Collection in St. James's Park is very limited in its use; and the Surrey Zoological Gardens is a pay place.

Putting Kew out of the question, the only places open even for artists are the Royal Botanic and Zoological Gardens; and more students of the Royal Academy than of the School of Design go to either—indeed, very few from the School of Design. It is true plants are used at the Schools of Design; but free study from the growing plant is what is most wanted. For the instruction of the public at large, the means are quite inadequate; and besides the Victoria Park, we would ask for botanic gardens at Battersea and Greenwich.

The bronzes at the French Exposition are well executed; and this branch of art, which includes clock-cases and gilt plate, is carried on far beyond us. One reason is, that silver plate here takes the place which in France is held by gilt bronze. The latter can hardly be said to have an existence with us; not because we have not the means of execution, but because the fashion and the material are different. The works of Eck and Durand, Marchand, Deniere, Matifere, Susse, and Villemsens, will be looked upon with admiration.

The specimens of cabinet-work are most remarkable for the inlaying. Grohé, Marcelin, and Marchal, have some excellent work. In design, carving, and finish, we think we can meet the French; but we have not yet reached them as to price. We would particularly direct the attention of our readers to some of the inlaying, and the prices charged for it.

For gilding, we are inclined to give the palm to the English; but they beat us in silks for upholstery. It is, however, rather in

the general design for decoration that they are our masters, than in separate articles of furniture.

There is one great specimen of paper-staining—a landscape by Zuber; and there is the Ascension, by Delicourt; but otherwise there is no great show in this way. We know, nevertheless, that the French beat us, and nothing can give us a fair chance for paper-hangings but more schools of design and botanic gardens, the removal of the excise on paper, and the abolition of the window duties; perhaps we ought to say the establishment of Mr. Cochrane's street orderlies, and street cleansing. Wanting light, and with horse-dung blown into our rooms and dignified with the name of dust, there is little inducement to set up these panoramas and other pictures, which are as entertaining as they are tasteful. Our manufacturers are starved out by an oppressive and neglectful government.

Of gold and silver plate there is little; and we are fully prepared to meet the French or any other manufacturers. Candelebra, epergnes, racing-cups, and other presentation plate, being the English fashion, where the French give Sèvres porcelain, Aubusson tapestry, or gilt vermeil. There are two objects that require a special consideration—swords presented to the Presidents of two Spanish-American republics. This, and a plan of the city of Mejico (Mexico), by Bauerkeller, put us in mind what a revenue the French manufacturers derive from Spanish-America. In Mexico, and throughout the South, there are swarms of French shopkeepers and pedlars; and the similarity of language favours a knowledge of Spanish tastes and propensities. This is quite neglected here; and, so far as we are aware, there is no public teacher of the Spanish language and learning in Liverpool, Manchester, Birmingham, Sheffield, or Glasgow, and the professors in the two London colleges have few scholars. A little attention to Spanish in our great seats of trade and manufactures, would give us a chance with fifty millions of Spaniards.

In jewellery of all kinds there is a very fair show, and we may name Daniel, Rouvenat, and Froment-Meurice; but there is nothing to frighten London and Birmingham, although the Parisians are great masters in these arts. There are some good works in gold, silver, steel, mother-of-pearl, tortoiseshell, and other materials.

Some of the shawls by Deneirouze, Gaussen and Pouzadoux, and Rosset and Normand, are very good, and will well repay examination.

The patterns and designs for silk, cotton, and tapestry are what will be looked at narrowly, for here is a stronghold of the French; and they have no unworthy representatives in Couder, Claude, Braun, Lobiensky, and others. Couder has designs of many classes, in each of which the style most suitable to the material is adopted. Here, as we have before hinted, the study of flowers and of natural history is very apparent, and the necessity for this was fully pointed out twelve years ago by the Committee on Schools of Design. If we are to beat the French, it must be with their own weapons; and in despite of the pig-headedness of our manufacturers, and the self-interested prejudice of academicians, the instruction in our schools of design must be of the highest class, and must be based on the study of nature, from the human figure down to the slightly-organised flower.

M. Mathias has specimens of the scientific works he has published, and of collections of technical works for public libraries. The exertions of M. Mathias should instruct us, for if public industrial libraries are necessary in France, so are they here. We may remind our readers that they have now an opportunity of purchasing works in those branches of science in which the French are proficient.

The zinc exhibition of the Vielle Montagne Company gives a very good illustration of the varied uses to which that metal is now being applied; and although zinc is much worked up here, still Flanders is the chief seat of production and supply, and this collection cannot fail to prove useful to many of our architects and engineers. The zinc mouldings and ship-sheathing are not among the least promising applications.

We shall now say a few words upon several subjects for which we have little space at our disposal. The painted glass is good; but we can equal it. There is some good carpeting; but there again we can come in. M. Le Molt has a simple galvanic battery and some philosophical apparatus. The lace shown by M. Guyot de Lisle is a worthy production of French skill. Some of the tapestries shown by M. Sallandrouze are wonderful—the brilliancy of oil-painting is approached; there wants only a varnish to complete the identity. The leather ornaments, by Dulud, are good, and almost equal in effect to the Cannabic composition.

The children's toys of M. Theroude should not pass unnoticed. The toy business employs a thousand people in London, and yet we import largely from the High Dutch. Carved ivory flourishes at Dieppe, and constitutes the staple of that town. The fancy stationery is very well represented, and is a branch of industry in which we are making progress, though the paper duty is heavily against us. M. Gruel has some bookbinding of a highly artistic character. M. Charpentier has some good chandeliers and lamps. There is an interesting specimen of wood mosaic, a figure of a monk.

Undoubtedly there is not that wealth in France there is here, neither are there so many wealthy men, but France has many compensations. There are better means of instruction, and the public are more tastefully trained; the government acts as grand patron. The church still creates a great demand for painting, carving, stained glass, vestments, tapestries, jewellery, and church furniture, even to artificial flowers. The great stay, however, is this, that Paris has created and enjoys a reputation for taste, which commands the orders of kings, nobles, and churches throughout the old world and the new. Paris has the market of the world—we, not even that of our own empire, for the French share, too, in this. The fight is for millions, and we have a good chance if we will but try—we are making good way; where we try we succeed, and we must go on. Those who deal with us for cotton and iron will deal with us for silks, paper-hangings, and cabinet-work; the market is as open to us as to the French; indeed, we have more commercial facilities, but we want instruction, and this is the direction in which exertion must be made. The exhibition of 1851 will only be worth anything as a means of public instruction; and therefore is it the more desirable all our rivals should be invited; but the whole organisation of industrial instruction must be strengthened. Drawing in the national schools, schools of design, with the live model, free industrial libraries, schools of chemistry and mechanics, botanic gardens, picture-galleries, art unions, freedom from excises and the tax on God's light; these are what we want to achieve success. The demand seems large, but the cost is small.

REGISTER OF NEW PATENTS.

STONEWARE PIPES.

BENNETT ALFRED BURTON, of John's-place, Holland-street, Southwark, London, for "*certain improvements in the manufacture of pipes, tiles, bricks, stairs, copings, and other like or similar articles, from plastic materials; also improvements in machinery to be employed therein.*"—Granted June 7; Enrolled December 6, 1849.

The object of this invention is to produce pipes and other articles from plastic materials of greater strength and durability, more regular in their structure, and of better finish, than has ever yet been accomplished. The manner in which the inventor effects this object is by compressing the plastic material of which pipes and other articles are composed, by a process of rolling; which is found not only to increase the strength of such articles as may be subjected to such process, but also to give them a smoother surface, so that they may be less liable to the accumulation of deposit; and in the case of pipes, will be found to offer less resistance to the passage of fluids.

The machine for making pipes according to this invention consists of a vertical framework, supporting two clay cylinders, so arranged that they can be brought alternately below the screw and piston, for the purpose of forcing the clay through the dies. The object of such an arrangement is to allow of one cylinder being filled during the process of forcing through the die the clay contained in the other cylinder.

To the centre part of the die (see fig. 1) there is attached a mandril *a*, the lower end of which just comes below the centre line of four rollers, turned and arranged as shown at fig. 2, which represents a plan of the rollers, and their bearings supported by a cast-iron frame *b*, *b*. The mode of driving the rollers is by a wheel *c*, keyed upon the end of the shaft *d*, of the fixed roller, and three pairs of bevel-wheels *e*, *e*, *e*. The wheel *e*, is driven by a pinion, keyed upon the end of the main driving-shaft of the machine, which shaft also gives motion, by means of an upright shaft and suitable gearing, to the screw, which forces the clay contained in the cylinder through the die. It will be seen on referring to the plan that the rollers will be drawn in one and the same direction, and with the same surface velocity.

The process of manufacturing pipes according to this invention is therefore as follows:—The clay, as it is forced through the die in the form of a pipe, slips over the mandril *a*. The length of

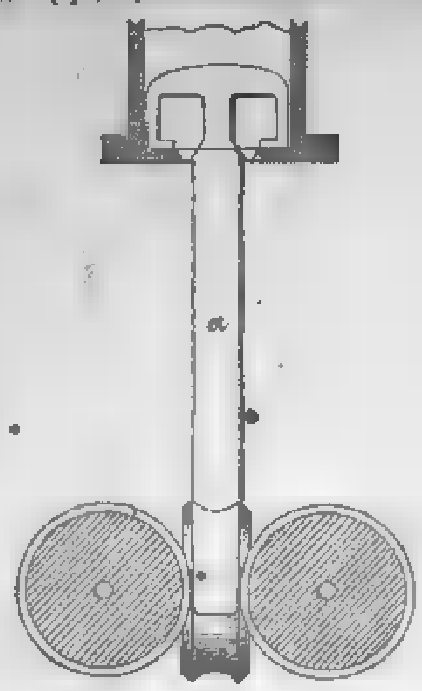


Fig. 1.

pipe required is then cut off, and afterwards drawn by the motion of the rollers over the end of the mandril, whereby the particles of matter forming the pipe become compressed or consolidated to such an extent, that when baked in the usual way they have been found, by repeated experiments, to be upwards of 75 per cent. stronger than pipes made from the same clay, but manufactured in the ordinary way; besides being more regular in their structure, and in every respect better finished.

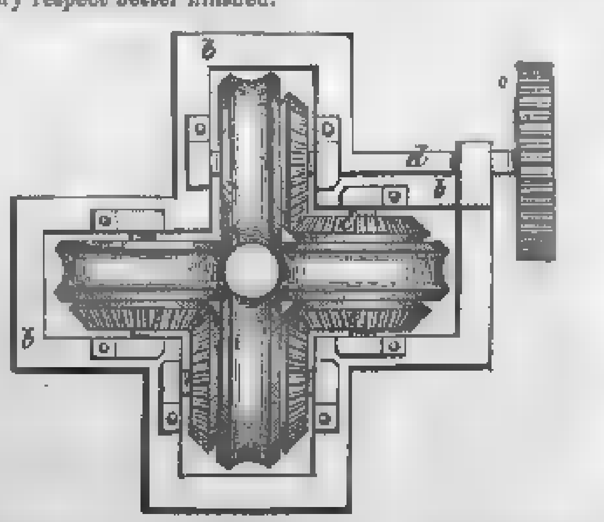


Fig. 2.

It will be seen from the above that the pipes are compressed immediately after passing through the die. This will, however, depend upon the nature and consistency of the clay, and state of the weather; for in some cases it may perhaps be desirable to let them stand in a dry place for two or three days previous to being rolled, which will entirely depend upon circumstances, and must be left in some measure to the judgment of the workmen: It will also be seen, with regard to pipes of small diameter, that the rolling machine would do a greater amount of work than a pipe machine having but one die. Pipes may therefore be made in a separate machine, having any required number of dies, and afterwards rolled. For this purpose, the specification describes a modification of the above machine, to be used for the purpose of compressing only.

In cases where the pipe is required to have a taper hole, the inventor employs a mandril made taper at the point, the mandril being gradually withdrawn by a screw or other suitable means, during the time the pipe is passing between the rollers.

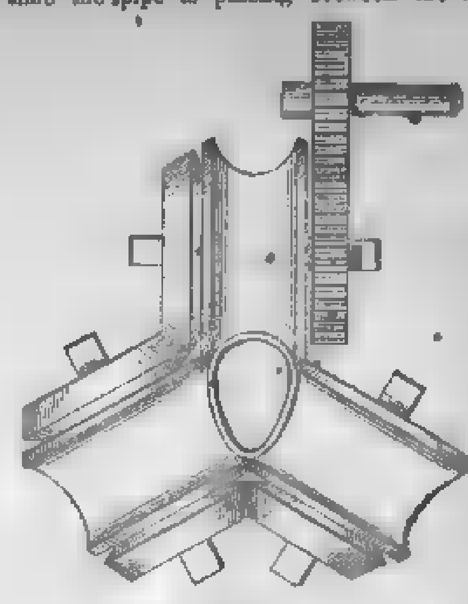


Fig. 3.

When the article to be compressed is not of a circular form, two, three, or more rollers may be employed, as the nature of the case may require (see fig. 3); which shows the form, mode of arranging and driving three rollers for compressing an oval pipe.

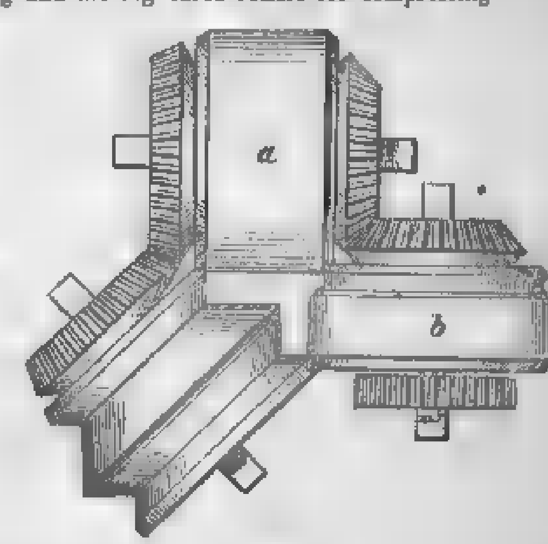


Fig. 4.

Fig. 4 shows the form, mode of arranging and driving three rollers for compressing a stairs' tread or step; the rollers *a*, and *b*, may, in this case, be engraved with any suitable device, or pattern, which will be impressed on the top side and front of the step, as

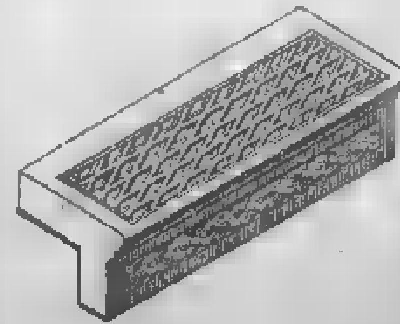


Fig. 5.

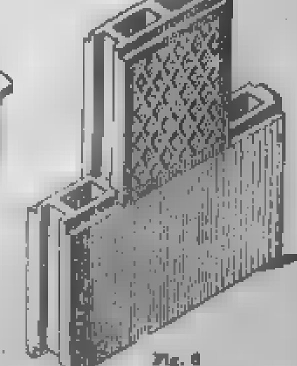


Fig. 6

shown at fig. 5, which represents an isometrical view of a step manufactured according to this invention.

Fig. 6, is an isometrical view of three hollow bricks, and the manner in which they fit together. Hollow-bricks or tiles, of the form shown in the drawing, are made by forcing clay through a die of suitable form, and afterwards compressing the clay, by passing it between four rollers, two of which are turned of such a form as to produce a rebate on the edges of the bricks; the other two being engraved on their peripheries, so as to produce on the sides of the brick or tile, any suitable device or pattern. The ends of the brick are rebated afterwards, in a separate machine.

Fig. 7.

The specification having described the mode of arranging rollers for compressing hollow bricks, copings, columns, and articles to be employed for building purposes, further states, that by the application of cams, eccentrics, or convolute rollers, articles of a variety of forms, so far as regards their length and tranverse section, may be produced by the process of rolling, as hereinbefore described.

Another part of these improvements relates to the mode of making bends for pipes; and consists in so constructing the die that a bend of any required curve can be produced, simply by forcing the clay or other plastic material through the die; whereby the moulds employed in the process of making bends as heretofore are dispensed with. Bend pipes, after they have been made as described in the specification, are afterwards compressed by passing them between rollers as described.

The specification, after describing several machines for cutting socket, or rebate and screw joints upon the ends of earthenware pipes, concludes somewhat as follows:—I would have it understood, that I do not claim as my invention the combination of four rollers, and mode of driving, as represented at fig. 2, the same having already been applied to the manufacture of iron pipes. But that which I do claim as my invention is—

First, the application of rollers turned of such a form, and arranged in such a manner, that they may be employed for compressing or consolidating the particles of matter composing pipes, tiles, bricks, copings, stairs' treads, pillars, columns, or other articles composed of plastic materials, intended for building, drainage, and other purposes.

Secondly, I claim the general arrangement and combination of parts composing the machines for making and compressing pipes, as hereinbefore described.

Thirdly, the mode of making bends for pipes, as described.

Lastly, the general arrangement and combination of parts composing the machines for forming rebate, or socket and screw-joints.

Experiments on Stoneware Pipes.

EXPERIMENTS *showing the relative strength of Pipes made in the ordinary manner, and by* A. and M. BURTON'S *Patent Machine.—"Unrolled" being the common pipe, and "Rolled" indicating that the pipe has passed through the Patent Machine.*

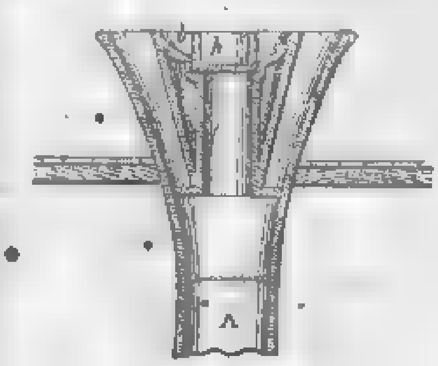
No. of Experiment.	Bore of Pipe in inches.	Thickness of Pipe in inches.	Length of Pipe in inches.	Weight of Pipe in lbs.	Breaking weight in lbs. pressure per inch.	Remarks.
1	2·812	·489	20·88	8 75	420	Rolled Fine Clay
2	2·67	·471	22·37	9 25	350	" "
3	2·67	·471	22·37	9·25	340	" "
4	2·68	·472	21·	7·75	180	Unrolled Fine Clay
5	2·7	·473	21·5	7·80	170	" "
6	2·9	·471	21·3	7·9	90	" "
7	2·75	·454	21·5	8 13	340	Rolled Coarse Clay
8	2 75	·460	22·81	8·25	270	" "
9	2·75	·465	22·37	8·25	260	" "
10	2·75	·5	21·37	8·25	140	Unrolled Coarse Clay
11	2·75	·489	21·37	8·5	120	" "
12	2·75	·475	21·47	8·36	110	" "
13	3·375	·458	23·12	12·25	660	Rolled Fine Clay
14	3·375	·646	22·75	12·25	580	" "
15	3·375	·650	24·12	13·75	500	" "

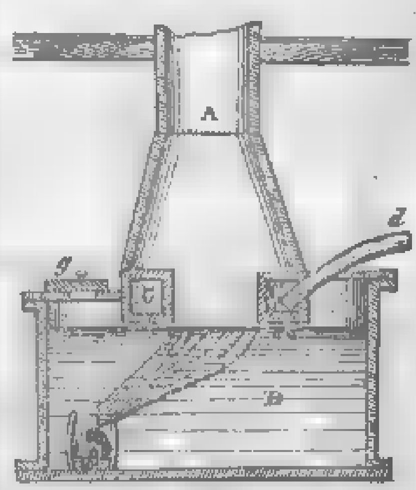
SHOT.

DAVID SMITH, of New York, United States of America, lead manufacturer, for "*certain new and useful improvements in the means of manufacturing certain articles in lead.*"—Granted May 29; Enrolled November 29, 1849.

The improvements relate to the manufacturing of "drop-shot," which are now formed by allowing molten lead to fall from a great height, the metal at the same time being separated by the pouring-pan into particles, according to the size of the shot to be manufactured. The falling of the lead through the atmosphere causes the particles to assume a globular form; and in order that such may be properly effected, it is necessary that the height of the fall shall be such, that the falling lead will acquire a certain velocity through the atmosphere; hence the necessity of erecting high towers for the purpose, which entails great outlay in the manufacture of shot.

To obviate this, the inventor proposes employing a height of about 50 feet, and yet at the same time obtaining an effect equal to a fall of 150 feet, or more if desired; and which is obtained by driving a current of air in a contrary direction, the effect of which, combined with the velocity of the falling lead, is equivalent to the ordinary heights employed. The annexed engraving is a section of the apparatus, for the purpose of carrying out this invention. A, is a vertical metal tube, about twenty inches in diameter, the lower end is enlarged in the form of a truncated cone, and rests on a chamber B, containing water, which forms as it were a base or pedestal for the whole. In the upper part of this vessel B, is an annular compartment C, the inner diameter of which is equal to the diameter of the tube A, and the outer diameter equal to the large end of the cone. The upper surface of this annular chamber is thickly perforated with holes, by which air is admitted to the body of the pipe; the air being forced into the annular chamber C, through the pipe *d*, from any blowing apparatus calculated to produce a sufficiency of blast to give the required velocity in the tube A. *e*, is a shoot to guide the shot into the vessel *f*, and which may be removed through the closed aperture *g*, when filled. The water rising up in the shoot *e*, receives the falling shot, while the inclosed water case prevents any escape of air from below. The current of air first entering the annular space C, becomes thoroughly diffused over the entire area of the pipe, by transmission through the numerous apertures. The upper part of the tube A, is surmounted by a trumpet-mouthed extension, the larger annular space affording ready egress for the air forced in at the bottom, while the centre is occupied by the pouring-pot *h*, which rests over a concentric cylindrical channel *i*, supported from a six-armed frame, secured in the tube at *k*. The pouring pot, as usual, is perforated at bottom, so as to separate and diffuse the lead over the area of the channel *i*; the pouring pot *h*, rests in, and is surrounded by a spill chamber *l*, to receive any lead that may run over, and intercept its descent through the tube.





The metal thus falling through a space of 50 feet, must have an upward current of air that will render it equal to the velocity attained in falling 150 feet. By increasing the current of air, an equivalent for any height of fall may be obtained. Instead of

blowing in air at the bottom, the same result may be obtained by exhaustion from the top or funnel mouth, the outer space of which must be inclosed and connected with some suitable exhaust apparatus, and in which case the annular chest at the bottom will be dispensed with, and free vent given for the ingress of air.

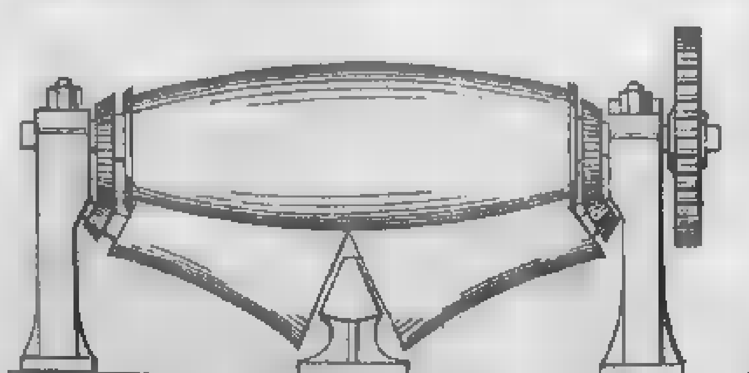
IRON CASKS OR VESSELS.

Solomon Israel Da Costa, of Great St. Helens, city of London, civil engineer, for "*improvements in vessels for holding solids or fluids, and in machinery for manufacturing such vessels.*"—Granted May 22; Enrolled November 21, 1849. [Reported in the *Patent Journal.*]

This invention relates—first, to an improved mode of constructing barrel-shaped vessels of iron, and also to machinery used in the construction of such vessels.

In the manufacture of these vessels the patentee forms the body part by bending the plate or sheet iron by means of rollers, somewhat similar to plate-bending rollers used for boiler purposes; the plate used being either such as will form either one-half of the vessel, or complete the entire circle. The upper bending or shaping roller, for this purpose, is formed of a barrel-shape (that is, larger at the centre than at the ends), more or less, according to the shape to be given to the plate; while the under roller is the reverse of the upper, so as to receive it and squeeze the plate between them. On the ends of the upper roller are two cutting discs, or edges, which pare the edges of the plate as it is passed between the rollers. A third roller is employed to guide and give the direction to the plate under operation, its proximity to and position with regard to the other rollers being adjustable for the purpose of bending the plate, more or less, according to the size of the vessel to be made, as well understood in the bending of boiler plates. The plate, after being heated red hot, is passed through the rollers, which, at one and the same operation, bend, shape, and trim the body part of the vessel.

The plate, after being bent, encircles the upper roller; and in order to remove it readily, the patentee forms one of the bearings of a spherical shape, which allows the opposite end to be raised, for the purpose of removing the bent plate. The rollers are so formed as to set back a small portion of the plate at each end, so as to form an enlargement for the reception of the ends of the cask; the enlarged end is of a cylindrical form, or rather slightly coned outwards, to render the ends more easily introduced and fitted. The ends are formed of plate-iron, having an edge turned up, which fits the enlarged part of the end, and is, after being fitted, brazed in its place; these casks are furnished with thickness rings at the bung and tap holes, such bungs being rivetted, or otherwise secured, in their position.



The annexed engraving represents in elevation a set of rollers of a different construction; instead of one lower roller being employed, two are substituted, the third or bending roller being the same as before described, but which is not shown in the engraving; these three rollers are geared together in such manner as to produce a like motion of their peripheries, or, as near as possible, taking the medium of their diameter. The cutters are here represented at either end of the upper roller, but the portion which is set back to form the enlargement of the end is omitted. The superfluous metal is cut off by the cutters passing or crossing the ends of the upper rollers. The action of these rollers will be sufficiently understood without further description. A third machine for this purpose, consists of two blocks, having semicircular cavities, opposed to each other, and which are drawn together or expanded by means of right and left hand screws, on a shaft; the plate having been partially bent, is introduced between the two blocks, and by drawing them together, completes nearly the entire circle. The hollows or cavities of these blocks are of the same barrel form, and in order to press the bent plate into which, the patentee employs a shaft, concentric with the hollow blocks, carrying between two crank-arms and a barrel-shaped roller; after the plate has been partially formed, the shaft is caused to rotate, by which the roller will be pressed and rolled round the interior surface of the vessel under formation, causing it to be compressed into the form or cavity in the blocks. The plate, while under operation, is made red hot as before.

The second part has reference to the manufacture of such articles as are usually struck or stamped in metal, for which purpose the patentee employs a press very similar to the ordinary screw-press, with dies—that is, male and female of the ordinary kind. But instead of using sheets or plates of metal, the patentee uses the metal in a molten or semi-molten state, which is deposited in the bottom of the female die, in sufficient quantity to produce the article required. The upper die is then brought down while the metal is still soft or in a molten state, by which it is caused to rise up and fill the space between the dies; a second depression of the upper die further imparting the impression to be imparted to the article. Where the impression is required to be sharper than can be obtained by this means, such articles may be again struck in the ordinary manner, by which much finer and sharper lines may be obtained, and with much less work than heretofore.

The third part refers to the manufacture of hollow-formed vessels in clay, cement, or other plastic material, which is somewhat similar to the foregoing mode of stamping metals, the object being to prevent the formation of bubbles or honeycomb in the articles so manufactured. The clay or other plastic material is placed in the bottom of the hollow mould, which, as in the last case, rises when the plunger or die is depressed, so as to fill the space for its reception, and give the required form to the article to be produced, and by which all bubbles or imperfections resulting from the confinement of air in the moulds are avoided.

The patentee claims: First—The improved vessel or cask, manufactured in the manner described; and also the machinery or apparatus for making the same.

Secondly—The mode of pressing up in moulds or dies, vessels or hollow forms, made in molten or semi-molten metal of any kind suitable for the purpose, so as to produce wholly or in part the shape required, and which shape may be again struck in another die or dies in the ordinary manner of striking up hollow metal goods, by which means a still sharper outline or finer impression may be obtained.

Thirdly—The method of making vessels or shapes of hollow forms in clay, cement, or other plastic material suitable for such hollow forms, and pressed upwards from below, which will prevent in a great measure the formation of air bubbles, such bubbles producing the vessel of a honeycomb and defective character; which mode of manufacture does not require the centre disc die, which in certain articles is necessary, and is usually placed at the bottom, and held by one or more cross-pieces, which separate the plastic form as it passes through, as for instance, in clay pipes.

ELASTICITY OF VAPOURS.

Sir—In reprinting, in your *Journal* for December, the principal portions of my paper on the Elasticity of Vapours (originally published in the *Edinburgh New Philosophical Journal* for July), I observe that the co-efficients of the formula for calculating the elasticity of the vapour of mercury have been omitted.

As that formula is of considerable utility in delicate observations of the elasticity of other vapours, I annex the co-efficients, in case you may wish to publish them.

The formula being $\text{Log}\cdot P = \alpha - \frac{\beta}{t}$,

α for millimetres of mercury	=	7·5305
„ for English inches of mercury	=	6·1259
Log β for the centigrade scale	=	3·4685511
„ for Fahrenheit's scale	=	3·7238236

I am, &c.

Edinburgh, Dec. 10, 1849. W. J. Macquorn Rankine.

DISCHARGE OF WATER THROUGH DRAIN PIPES.

Experiments on the Discharge of Water from Pipes, made under the sanction of the Metropolitan Commissioners of Sewers.—[From the *Mechanics' Magazine.*]

I send, for the guidance or consideration of your readers, some account of experiments made on the discharge of water from pipes, with a view to ascertain the requisite sizes of various aqueducts for the purposes of drainage. It was necessary to conduct these experiments, as to arrangements of apparatus, in a different manner than if it had been required to know the necessary sizes of pipes for supplying the town with water, as, in the former case, there being no pressure arising from head, a flow of water of uniform section is maintained by the continual addition of lateral streams, and the length of the aqueduct, therefore, as an element of friction, may have little or no influence on the velocity of the main current; while in the case of waterworks, the velocity of the water depending on the head at the origin of the system, length of pipe is a most important element in calculation; and the friction arising from this condition is often the chief force to be overcome. In fact, under these two circumstances, reverse effects are produced: for in a drain, if the length be increased, and junctions be proportionally added, a greater amount of discharge will be the result (I always assume that the junctions are made in the most scientific manner with regard to their aiding the main line); and in another respect the operations of a system of drainage and a system of waterworks are curiously dissimilar; for, in the former, the chief current being supplied immediately by its tributary mains, sustained by their various ramifications, and ultimately fed by a multitude of small mouths, the whole operation proceeds naturally and easily by the silent effort of gravitation; while in the latter case, the main line being first charged, the water has to be forced with sufficient power to divide itself, and move with great velocity in a multitude of different directions, up hill and down hill, through intricate and narrow passages, turning at every variety of angle. In the latter work, again, the power is generated at once at the head of the system, and is continually being expended so long as it acts; but in the former, force is self-generating—it accumulates as the operation enlarges, until the small tributaries become important streams, and these streams an impetuous torrent. It is easy to perceive at once what an important part *friction* plays in the one case to what it does in the other.

Hence, with regard to *formulæ* constructed on the basis of experiments made with heads of water at the ends of pipes, they have proved totally useless as means of ascertaining the proper sizes of drains and sewers; and when tested by the actual discharge of a drain, I have found them so much in error that I could have guessed by the eye much nearer the truth. The *formulæ* of Prony, Dubuat, Eytelwein, Genieys, Young, Smeaton, and others, not only each of them departs very wide of the truth when applied for the purposes of drainage, but they all disagree the one with the other, so much as to destroy confidence in any one of them, unless confirmed by other evidence. The experiments which I am about to describe were made under the sanction of the Metropolitan Commissioners of Sewers, on their premises in Greek-street.

The apparatus used was as follows:—A strong platform, 100 feet long, was erected, fixed to move about a central axis at one end, and free to be moved at the other by a chain and windlass, so as to afford a range from the horizontal plane to a declivity of 1 in 10. A tank, holding 1600 gallons, was placed at the upper end; and another tank of sufficient dimensions, received and measured the water discharged at the lower end. On this platform lines of pipes, varying from 3 inches to 12 inches diameter, were tried. The pipes consisted of the ordinary Vauxhall stoneware, in two-feet lengths; and a careful selection of them was made as to accuracy of bore and dimensions. They were laid in straight lines of uniform inclination, and the pipe joints were rendered water-tight with clay. On each side of a line of pipes, five junctions were attached at intervals, by which the water was admitted, as well as at the head of the pipe. The entrance of the water was regulated by sluices; so that while the head of the pipe was just filled, water was at the same time admitted by the junctions sufficient to maintain the pipe full throughout its entire length. Under these circumstances, we found—to mention only one result—that a line of 6-inch pipes, 100 feet long, at an inclination of 1 in 60, discharged 75 cubic feet per minute. The same experiment, repeated with the line of pipes reduced to 50 feet in length, gave very nearly the same result. Without the addition of junctions, the transverse sectional area of the stream of water near the discharging end was reduced to one-fifth of the corresponding area of the pipe, and it required a simple head of water of about 22 inches to give the same result as that accruing under the circumstances of the junctions. With regard to varying sizes and inclinations, we found, sufficiently for practical purposes, that the squares of the discharges are as the fifth powers of the diameters; and again, that in steeper declivities than 1 in 70, the discharges are as the square roots of the inclinations; but at less declivities than 1 in 70, the ratios of the discharges diminish very rapidly, and are governed by no constant law. At a certain small declivity, the relative discharge is as the fifth root of the inclination; at a smaller declivity, it is found as seventh root of the inclination; and so on as it approaches the horizontal plane. This may be exemplified by the following results found by actual experiment:—

Discharges of a 6-inch Pipe at Several Inclinations.

Inclination.	Discharges in 100ft. per minute.	Inclination.	Discharges in 100ft. per minute.
1 in 60	75	1 in 320	49
1 in 80	68	1 in 400	49·5
1 in 100	63	1 in 480	48
1 in 120	59	1 in 640	47·6
1 in 160	54	1 in 800	47·2
1 in 200	52	1 in 1200	46·7
1 in 240	50	Level	44

The series of hydraulic experiments from which the foregoing is selected, has been in operation for the last two years, at an expense of upwards of 2000*l.* The experiments conducted at Greek-street were a continuation of similar experiments made in the Fleet sewer: in the latter place the sewage was used, and in the former pure water supplied by the New River Company.

The conclusion arrived at is, that the requisite sizes of drains and sewers can be determined (near enough for practical purposes, as an important circumstance has to be considered in providing for the deposition of solid matter, which disadvantageously alters the *form* of the aqueduct, and contracts the water-way) by taking the result of the 6-inch pipe under the circumstances before mentioned as a *datum*, and assuming that the squares of the discharges are as the fifth powers of the diameters.

That at greater declivities than 1 in 70 the discharges are as the square roots of the inclinations.

That at less declivities than 1 in 70 the usual law will *not* obtain; but near approximations to the truth may be obtained by observing the relative discharges of a pipe laid at various small inclinations.

That increasing the number of junctions at intervals accelerates the velocity of the main stream in a ratio which increases as the square root of the inclination, and which is greater than the ratio of resistance due to a proportionable increase in the length of the aqueduct. The velocities at which the lateral streams enter the main line, is a most important circumstance governing the flow of water. In practice, these velocities are constantly variable, considered individually, and always different considered collectively, so that their united effect it is difficult to estimate. Again; the same sewer at different periods may be quite filled, but discharge in a given time very different quantities of water. It should be mentioned that in the case of the 6-inch pipe, which discharged 75 cubic feet per minute, the lateral streams had a velocity of a few feet per second, and the junctions were placed at an angle of about 35° with the main line. It is needless to say that all junctions should be made as nearly parallel with the main line as possible, otherwise the forces of the lateral currents may impede, rather than maintain or accelerate the main streams.

The conclusion of the labours of the authors of the several formulæ before quoted, left the science of hydraulics in such a state that no man, except by his own practical observation, could tell what an aqueduct, under any given conditions, would discharge. This will be so apparent to any one who will take the trouble to examine and compare the various formulæ the one with the other, and to test their general pretensions by some known facts, that I need dwell on it no longer. It would be a valuable thing if practical men would make a common record of facts occurring in their own experience,—*facts, not conclusions derived.* No doubt the facts exist in sufficient abundance; but they are too scattered, or appropriated as secrets, so that the engineer is often obliged to assume results which he has not had an opportunity of verifying by practical experience. Had such a record been current, the formulæ of the hydraulicians could not have been received as orthodoxy by the scientific world.

1, *Greek-street, Soho,*
Dec. 4, 1849.

J. L. HALE,
Civil Engineer.

THE RUDIMENTARY TREATISES.

Rudimentary Dictionary of Terms used in Civil Architecture, Naval Architecture, Building and Construction, Early and Ecclesiastical Art, Civil Engineering, Mechanical Engineering, Fine Art, Mining, Surveying, &c. By JOHN WEALE, Author of 'Divers Works of Early Masters in Christian Decoration,' &c., &c. London: Weale, 1850.

The booksellers in Berlin have lately been subjected to a grievous oppression—the necessity of reading the books they publish or sell. Grocers, they say, never eat figs,—booksellers do not read books; and the Berlin booksellers have remonstrated against the tyranny of the police, which subjects them to the task of reading the contents of their own shelves. With the booksellers we take part, if only for this reason: that the police are throwing away their resources—disarming justice of her sharpest edged sword; for if the reading were only enforced at the proper time, and reserved as the punishment of offences instead of an engine of prevention, we believe the law would be armed with greater terrors. There are booksellers in London, no less than in Paris and Berlin, to whom we would not bate one page of the nauseous and nonsensical trash which they have been guilty of giving to the world; and the *lex talionis* dictates they should be duly punished by its perusal.

From reading to writing there is, however, a step; and upon that booksellers but seldom venture, though there are some distinguished men in that business who have not hesitated. It is not necessary that every man among them should be put to the test; but it is gratifying to see they can take the pen in their hands, and that they have a practical knowledge how a book ought to be written. Mr. Weale, it is true, is not a new writer, but nevertheless there is no harm in making a commentary on his proceedings, for a man is likely to be none the worse judge of a book who can write one himself. For a man to be a good and enterprising publisher, he must have some knowledge of the requirements of the public, and the means of gratifying them; and just in proportion to his own knowledge and the interest he feels, will be the measure of his exertions. A kindred zeal for the welfare of the pursuit with which he is connected, will sometimes prompt him to produce works of a higher class than his temporary interests would appear to justify. He must be beyond his customers rather than merely up to their mark; he must lean to the authors rather than to the book-buyers; for if he only follow the taste of the public, the taste of the public is not likely to make a forward movement. A publisher may suit the taste of the public to a T, and yet only produce marrowbone-and-cleaver polkas; or he may humbug, shave, and softsawder the public in another line, and spend thousands in engraving royal marriages and christenings, and such miserable flunkeyism, when a like expenditure in the hands of a Boydell would give lasting glory to English art. Mr. Carter Hall has been the means of rendering essential service to the English school, by publishing in the *Art-Journal* the small engravings of the Vernon Gallery; while, if we turn from him, a literary man, to the print-publishers, we find that those who have the means, completely misuse them, and while making enormous profits bring the arts into contempt. The Art Union and the print publishers would be enough to swamp English art, if it depended on them alone.

We are, therefore, for the march of intellect and education; for having educated writers, educated artists, educated critics, educated publishers, and an educated public. An enlightened publisher will often be called upon to carry out an enterprise of considerable importance and considerable risk—nay, he may even suggest it; and we are sure bookselling has been none the worse for such men as Messrs. Charles Knight, Lovell Reeve, and John Weale. Charles Knight's love of Shakspeare has made a Shakspearian era, at a time when Shakspeare has been unshrined in his greatest temples, and left to the incense of his meanest priests. Mr. Knight has also taken a great share in those popular works under his name which have done so much for the spread of knowledge. Had he been less in love with his subject, he would have done less.

The Dictionary of Terms is a kind of introduction to the Rudimentary works—a series which we make no question will do very much good to the cause of education. It was, it seems, Colonel Reid, the author of the 'Law of Storms,' who gave the first hint for this series. At Bermuda, and afterwards at Barbadoes, he took a personal interest in the construction of several useful works; and he saw the lamentable want of knowledge of the West Indian workmen. For the commonest work, not only an engineer must be sent out, but workmen; and this is one of the great obstacles to West Indian progress. The introduction of Mr. Gordon's iron lighthouse, and of Messrs. H. O. and A. Robinson's sugar mills, which have boiler and rollers on the same platform, are therefore most useful in the islands; for what would here be simple machinery, cannot, out there, command the services of a good blacksmith. It is further to be observed, that the planters are not by any means fitly taught; for they go out from England raw lads, and learn little after: and it is not, therefore, to be looked for that they should teach negro carpenters and blacksmiths. As one means of instruction, Colonel Reid forwarded to Mr. Weale a copy of Professor Fownes's Rudimentary Chemistry, with a recommendation that it should be printed; and it was adopted as the first of the new series. We believe we are right in saying that not only in the West Indies, but likewise in the East, many of these Rudimentary works have been distributed by the government for popular instruction.

Pinnock's Catechisms were good compilations in their day. They formed a popular cyclopædia, a curriculum of education, which, for completeness, has not yet been equalled; and in language, no less than in many branches of science, they have been the means of greatly promoting the love of knowledge. It was not that a ninepenny treatise was held forth as self-sufficient for the acquirement of any branch of knowledge, but it was a preparatory step—as an introduction, and as an incentive. Just in the same way as Pinnock's Child's First Book, English Grammar, and Geography, led the way to larger works, so did the catechism of Greek Grammar, or of Hebrew Grammar, lead many a lad to more laborious studies. He bought a small book which was cheap, and promised to be easy; and he was enabled, by its perusal, to judge whether there was sufficient encouragement for his further study.

The works of the Useful Knowledge Society are of a very different class; they are calculated for students of a higher class, and are works of an original character: but although they provide for science and history, they do little for letters or language. They supplied one defect, but they do not meet another. In a country like this, with its peculiar political organisation, the life of a young man is no less occupied in the preparation for his political career than in the attainment of those special branches of knowledge peculiarly useful in his ordinary business. Literature enters largely into his amusements; the composition of lectures, the preparation for the discussion class, the studies for the elocution class, the acquisition of the knowledge of Latin and French, which he neglected in boyhood, or could not then learn,—all these take up much time and attention in the literary and mechanics' institutions, no less than with the self-student; and it is a capital defect to prepare a course of educational works which does not provide for these wants. Indeed, the cause of science would be as much promoted by the completion of the circle of knowledge in this way, as by any direct contribution.

In our view, there can be no greater mistake, so far as higher or supplementary education is concerned, than the restriction to empiric instruction. As all the law codes written do not embrace all the forms of litigation, and as all the medical works do not embrace all the cases of disease, so neither can all the books ever written meet all the contingencies of practice. The lawyer, the surgeon, or the engineer, is called upon to act for himself—and then it is he wants something beyond his books. The best works on geometry, and the best works on algebra, will be insufficient of themselves alone to constitute sound reasoners; and they too often have the tendency to narrow the mind rather than to enlarge it. When from abstractions or recognised definitions we come to language, the ambiguous vehicle of thought, the self-taught mathematician is found as perverse, as prejudiced, and as unsound, as any other imperfectly educated man. It is for this reason we object to mutilated studies and mutilated schemes of educational works, when too there is so much to be done. We are sure the Useful Knowledge Society would have done great good in producing uniformly with their other books, good treatises on logic and rhetoric, an idiomatic English grammar, a manual of philology, grammars of the modern languages in conformity with modern science, a work on drawing, as an instrument for training in habits of observation, some decent compositions on political geography,—aye, and they might go further, and let the public know something of ethnology, ontology, the study of the fine arts, the art of teaching, and many other things, old and new, on which there are no good and cheap popular works.

The French have a cheap popular series called the Manuels Roret, ranging in price from two shillings to four or five, which include not merely every branch of science, but every trade and profession. Charles Knight has published some small manuals for

trades, but we still want a class of works to answer the purpose of the Manuels Rorets; indeed, had not other occupations prevented us, we should long since have carried out the design we had formed of publishing such a series.

Chambers's Elementary works go almost as low down as Pinnock's in the class for whom they provide, and are nearly as extensive in their range of subjects. Although they have made many branches of knowledge popular, they are rather to be ranked as compilations than as original works.

We have hinted we prefer, as far as possible, works of an original character, rather than simple abstracts of other writings; and do prefer such, because a work of education should be expressly written for the class which it is intended to benefit. The writer, too, must write more with the mind of a student than an author—he must begin as a beginner, and not as a master: and yet that is seldom to be found in any of these elementary works which we have seen. They are rather abridged works of reference, of the class of Maunder's 'Treasuries of Knowledge,' than finished introductions to study. The fear of being tedious, the shame of being tautological, the love of praise, and perhaps the vanity of frippery and fine writing, dazzle and delude the author—and the student is lost sight of. Then, too, one who has learned quickly and well is often a bad master,—to him the manner of teaching and learning is indifferent, for he could learn any way: but not so with the student. Indeed, too much care cannot be taken in this, which is the right way; whereas now, half the care is thrown away because it is bestowed in the wrong way.

Mr. Weale's series certainly does not sin under the head of originality, for many of its parts are already standards in their respective branches; and, as with the Penny Cyclopædia, we shall see that a cheap and popular work may well be a good one, and a step in the cause of science.

We have said so much of elementary works generally, that we have left ourselves but little room for Mr. Weale's individual contribution, which is a very useful one. A cheap dictionary of terms was much wanted, for the field of engineering exertion is now so wide, and the two kindred pursuits of architecture and engineering have so many points of contact, that to most people, and particularly the public, such a guide was indispensable. The author has many peculiar opportunities for such a compilation, and he has fully availed himself of them, so as to embrace much interesting and valuable matter. If he has been occasionally discursive, he has claimed the privilege beforehand, and has therefore the right to be so. There are many things to be found which are elsewhere only to be met with in expensive works.

A Visit to the United Service Institution. By Lieut. D. B. SHAW, K.S.F. London: Parker and Co., Whitehall. 1850.

This little *brochure* should be read *after* the visitor has once gone over this interesting museum, and, as admission is so easily procured, revisit with this work in his hand, and examine more carefully the various subjects he treats upon. The author appears to make one of the party visiting the Institution, and points out everything of interest, doing away with the monotony of a catalogue, as he explains the most rare and curious specimens that are in the museum: the description of the uses of the different arms employed in ancient warfare is most interesting, and those of the South Seas and adjacent countries, together with those of India and China, show that he has made himself familiar with his subject. His description of the Naval and Military Model rooms are invaluable to the student destined for the profession of arms, as he points out many useful hints that might otherwise be overlooked. The specimens of Natural History are given to the visitor in order to bring under his notice those animals and reptiles with which some anecdote is attached. The Antiquities and Ethnological collection has been most masterly handled, and the anecdotes connected with the different subjects most amusing. The Library, which appears to be the *sanctum* of the members, seems replete with every work connected with the services.

The author's object has been to arouse the lethargic spirit which appears to pervade the services, and, as he truly states that this is the *only* Institution belonging to them, he calls upon those officers who compose her Majesty's service, to rally round it as a standard, and give it that support it ought so deservedly get from the profession.

SIR ISAMBERT MARC BRUNEL.

We have to record the death of this celebrated engineer, which melancholy event took place on the 12th ult. For the following memoir we are indebted to the *Times*:—

Sir I. BRUNEL by birth was a Frenchman, but his life and genius were almost wholly devoted to the invention and construction of works of the greatest public utility in this country. He was born at Hacqueville, in Normandy, now in the Department de l'Eure, in the year 1769; a year since remarkable for having given birth to many eminent men. His family has for many centuries held, and now hold, the estate on which he was born; and the name of Brunel is found constantly mentioned in the ancient archives of the province. He was educated for the church, with the prospect of succeeding to a living, and was accordingly sent at an early age to the seminary of St. Nicain, at Rouen. But he soon evinced so strong a predilection for the physical sciences, and so great a genius for mathematics, that the superiors of the establishment recommended he should be educated for some other profession than that of the church. His father strongly objected to his adopting the profession of an engineer, as one more likely to prove beneficial to others than himself, and he therefore determined that he should be educated for the naval service, in which he thought his son's proficiency in mathematics might lay the foundation of his advancement in that profession. At the proper age he entered the royal navy, being indebted for his appointment to the Mareschal de Castries, then the Minister of Marine. On one occasion he surprised his captain by producing a sextant and quadrant of his own construction, and which he used for making observations. He made several voyages to the West Indies, and returned home in 1792. At this time the French Revolution was at its height. As Mr. Brunel entertained Royalist opinions, which he was not very careful to suppress, his life was more than once in danger, and he was, like many others at that time, forced to seek safety in flight. He emigrated to the United States, where necessity, fortunately, compelled him to follow the natural bent of his mind, and to adopt the profession of a civil engineer. He was first engaged to survey a large tract of land near Lake Erie. He was employed in building the Bowery Theatre, in New York, which not many years ago was burnt down. He furnished plans for canals, and for various machines connected with a cannon foundry then being established in the state of New York. About the year 1799 he had matured his plans for making ship blocks by machinery. The United States was not then the field for so inventive a genius as Brunel's. He determined upon visiting England and offering his services and plans for this purpose to the British Government. Lord Spencer, then, we believe, First Lord of the Admiralty, became his friend and patron. He became a frequent guest at Spencer-house, and never failed to speak warmly of the assistance and encouragement he derived from the friendship of Lord and Lady Spencer. From this time he continued to reside in England, and refused to entertain many propositions made to him to leave England and settle abroad under the auspices of other governments. After much opposition to his plans, for a very powerful interest was arrayed against him, not lessened in that day by his being a Frenchman, he was employed to execute them in Portsmouth dockyard. To perfect his designs and to erect the machinery was the arduous labour of many years. With a true discrimination, he selected Mr. Henry Maudslay to assist in the execution of the work, and thus, possibly, was laid the foundation of one of the most extensive engineering establishments in the kingdom, and in which, perhaps, a degree of science and skill has been combined and applied to mechanical invention and improvement scarcely exceeded by any other in the world. The block machinery was finished in 1806, and has continued ever since in full operation, supplying our fleet with blocks of a very superior description to those previously in use, and at a large annual saving to the public. It was estimated at the time that the saving, in the first year, amounted to 24,000*l.* per annum; and about two-thirds of that sum were awarded to Mr. Brunel. It is needless to describe the originality and beauty of this well-known machinery. Even after the lapse of 40 years, notwithstanding the marvellously rapid strides we have made in the improvement and construction of machines of all kinds, it remains as effective as it was when first erected, and unaltered. It is still an object of admiration to all persons interested in mechanics. A few years afterwards he was employed by government to erect saw-mills, upon a new principle, in the dockyards of Chatham and Woolwich. Several other inventions were the offspring of his singularly fertile mind about this time,—the circular saw, for cutting veneers of valuable woods; and the beautiful little machine for winding cotton thread

into balls, which greatly extended its consumption. About two years before the termination of the war, Mr. Brunel, under the countenance of the Duke of York, invented a method of making shoes for the army by machinery, the value and cheapness of which were fully appreciated, and they were extensively used; but the peace of 1815 lessening the demand, the machinery was ultimately laid aside. Steam navigation also at that time attracted his attention. He was engaged in the building of one of the first Ramsgate steamboats, and, we believe, introduced the principle of the double engine for the purpose. He also induced the Admiralty to allow him to build a vessel to try the experiment of towing ships out to sea, the possibility of which was then denied. Many other objects of great public utility occupied his mind, which in this mere outline of a long and active life must be excluded.

The visit of the Emperor Alexander to this country, after the Peace, led him to submit to the Emperor a plan for making a tunnel under the Neva, where the accumulation of ice, and the suddenness with which it breaks up on the termination of winter, rendered the erection of a bridge a work of great difficulty. This was the origin of his plan for a tunnel under the Thames, which had been twice before attempted without success. In 1824, however, a company was formed, and supported by the Duke of Wellington, who took from first to last a deep interest in the work. Many men of science also joined it, amongst whom the late Dr. Wollaston was the most prominent, and whose brother long continued one of the most active and able promoters of the scheme. The work was commenced in 1824. It was stopped more than once during its progress by the breaking in of the river, and more effectually at last by the exhausted finances of the company, which never extended beyond the command of 180,000*l.* At length, after the suspension of the work for many years, by a special act of Parliament, a loan was sanctioned. The Exchequer Loan Commissioners advanced the funds necessary for the completion of the work under the river, and, notwithstanding many weighty professional opinions were advanced against the practicability of the work, from both the loose alluvial nature of the soil through which it had to be constructed, and the superincumbent flood of water, it was finished and opened to the public in 1843. In a scientific point of view this work will always be regarded as displaying the highest professional ability, an amount of energy and perseverance rarely exceeded, and a fertility of invention and resources under what were deemed insurmountable difficulties, which will alwys secure to Sir I. Brunel a high place amongst the engineers of this country. During Lord Melbourne's administration Mr. Brunel received the honour of knighthood, on the recommendation of the late Lord Spencer, then Lord Althorp.

Sir I. Brunel was a vice-president of the Royal Society, a corresponding member of the Institute of France, and a vice-president of the Institution of Civil Engineers. He was a Chevalier of the Legion of Honour. He was unaffected, simple in his habits, and benevolent, and as ready to do a kind act as he was to forget an injury. He died in his 81st year, after a long illness, which first visited him soon after the completion of the Tunnel. The care, anxiety, and constant strain of body and mind, brought on a slight attack of paralysis, from which he never thoroughly recovered. He leaves a widow, Lady Brunel, one son, the eminent engineer, and two daughters, the eldest married to Mr. Hawes, the Under-Secretary of State for the Colonies, and the youngest to the Rev. Mr. Harrison, the vicar of New Brentford.

PROCEEDINGS OF SCIENTIFIC SOCIETIES.

INSTITUTION OF CIVIL ENGINEERS.

Dec. 4, 1849.—JOSHUA FIELD, Esq., President, in the Chair.

The discussion was continued on Mr. PATON'S "*Description of the Southend Pier, and the ravages of the 'Teredo Navalis,' and other Marine Worms,*" and was extended to such a length as to preclude the reading of any original communication.

Numerous specimens were exhibited, and commented on, of timber thoroughly perforated by worms; whilst beside them, under the same circumstances, the "Jarrow wood," from Australia, was shown to have remained completely free from injury.

The reference to the age of Homer, as an instance of the ravaging habits of the *Teredo*, induced a return to geological questions; and it was shown that in the London clay, remains had repeatedly been found of timber perforated by sea worms. The oolite and greensand formations also exhibited petrified wood, filled with boring moluscæ. This led to the consideration of the formation most likely to withstand the attack of the *Pholas*; and it was shown, that the Portland stone was, from the quantity of silica it contained, least liable to be attacked.

The *Pholas* was shown to have been in active operation upon certain rocks from their earliest periods, but never upon Portland stone. Hence it was argued, that kind of stone should be used for breakwaters and other works exposed to the action of the sea.

The early state of the *Teredo* was noticed; when escaping from the egg, in the shape of a free swimmer, it was drifted about with the tide until it met with a log, a pile, or the side of a ship, to which it attached itself, and making an inroad into it, became a non-locomotive animal of different form and habits, never again to leave the habitation it had burrowed for itself in the body of the timber. The question of whether the boring operation of the marine worms was carried on by chemical, or mechanical means, was lengthily discussed. The thin shell, covered by its delicate membrane, was instanced as not possessing strength enough to cut away timber; but it was on the other hand shown, that the shape of the two shells, forming the extremity of the animal, admirably adapted them for powerful cutting, or rasping tools, when moved rapidly in a circular direction, as was evidently the case, from the uniformly cylindrical character of the holes.

The shells of the *Pholas* were also shown to be used in that manner, and the opinion appeared generally to lean to mechanical cause for the effects observed.

This bearing of the discussion naturally induced remarks upon the ravages of the white ant of India; which, however, appeared to have been little studied, and less understood, as far as attempting to arrest, or to prevent its inroads.

The various materials, such as Kyan's corrosive sublimate of mercury, Sir W. Burnett's chloride of zinc, Margary's salts of metals, Payne's combination of muriate of lime and sulphate of iron, forming in the timber an insoluble compound, and Bethel's creosote, or oil of coal tar, were discussed. All had their partisans, and were stated to have succeeded and failed under certain circumstances. Specimens of piles from Lowestoft harbour, whose waters were notoriously full of worm, showed that timber in a natural state was in a few months thoroughly perforated by *Teredo* in the centre, and *Limnoria* on the surface; but that piles, which had been properly saturated according to Bethel's system, in exhausted receivers, and subjected to such pressure as insured the absorption of about ten pounds' weight of the creosote, or oil of coal tar, by each cubic foot of the timber, were perfectly preserved from attacks of marine animals of any kind.

In one instance a partially "creosoted" pile had a notch cut into it, deeper than the impregnation had extended; a *Teredo* made its entry, and was found to have worked in every direction, until it arrived within the reach of the creosote, when the animal turned away and eventually left the pile.

Bethel's system was admitted, by all the speakers, to be that which hitherto, after many years' experience, had afforded the most satisfactory results.

Some most conclusive experiments, instituted by Mr. Rendel at Southampton, were stated to have produced the same results; and at Leith all the piles were weighed before and after their saturation, to insure their absorbing the full allowance of at least ten pounds per cubic foot.

Dec. 11.—The paper read was "*On the facilities for a Ship Canal Communication between the Atlantic and Pacific Oceans, through the Isthmus of Panama.*" By Lieut.-Col. LLOYD, Assoc. Inst. C.E.

In treating this subject, which, on account of recent events, has become one of great importance to the political and the mercantile world, the author brought to bear all the knowledge and experience acquired during a lengthened residence in South America, when serving in the Columbian Engineers, under General Bolivar, from whom, after much difficulty, he obtained permisson to make the first survey of the Isthmus, which he accomplished in the most complete manner, as well as making soundings throughout the principal rivers and in the chief harbours; compiling, at the same time, a mass of minute and valuable information relative to the country, which he transmitted to the Royal Society, in whose archives they were deposited, and a paper on the subject was published in the *Philosophical Transactions* in 1830. Thus may Great Britain claim not only the projection of one of the greatest works of modern ages, but also for one of her sons the merit of having, for the pure love of science, been the first to demonstrate the facility of the accomplishment of that, which so many have since

descanted upon, and, to some extent, appropriated without acknowledgement.

The general views of the author incline to the formation of a ship canal, in preference to a railroad; he denies that there are any obstacles to its accomplishment, but, on the contrary, asserts so many local advantages to exist and to be concentrated nearly at one point, that in after ages it will be a matter of wonder why so many generations should have neglected, or refused to render them available, towards the establishment of this long-coveted communication between the two Oceans.

The paper first reviewed the surveys of Garella, of Morel, and others, who had examined the country subsequently to Colonel Lloyd. It then examined the various lines proposed, and gave reasons for preferring that which, starting from the beautiful Bay of Limon, would proceed by a short canal, through a flat country, to the River Chagres, thence up the River Trinidad, as far as its depth would suit, and then cutting a canal into the Rio Grande, debouching at Panama. This line, it was contended, in the present state of the science of engineering, presented no obstacles, excepting the climate and the expense, to prevent a canal being cut of sufficient depth and dimensions to float, from one river to the other, the largest ship in her Majesty's navy.

The climate was stated, from personal experience, to be quite as good as in any tropical country, except in some particular spots, where, from local causes, certain complaints were rife.

The expense could only be accurately estimated by the survey of experienced engineers; but in a country abounding in fine timber, and the best building materials of all kinds, whilst no great chain of mountains, as had been fancifully depicted on suppositious charts, had any existence except in the imagination of the designer, it was only fair to allow, that the cost of a canal of such limited length could not be very great, and the supply of water might be presumed to be ample, in a climate where there was copious rain for nine months in each year.

The disadvantages of a railroad in such a humid climate, were descanted upon at length, and it was shown that the risk of injury to merchandise from that cause alone, independent of that to be anticipated from breakage and pilfering, during the various transshipments, must induce preference for a canal, through which vessels should pass from sea to sea without delay, and continue their voyage to their destination without breaking bulk.

The means of accomplishing the work were then fully considered. The proposition for a certain number of convicts, to be contributed by Great Britain, France, and America, was shown to be untenable; but it was argued, that a portion of the convicts from this country might be more advantageously sent there than to our present penal settlements. The means of preventing their escape were shown, and a proposition made for introducing with them a number of convicts from Bengal, and the other presidencies, whose language and habits would effectually prevent their mingling with the British convicts, whilst their power of enduring fatigue under a tropical sun, and during rains, and their simple mode of living, would render them valuable pioneers for the more robust Englishmen. It was stated also, that a great deal of native labour might be obtained at a cheap rate; sixpence, or ninepence per day, and his rations, consisting of a pint of rice, a pound of dried beef, and a *golpe d'aguardiente*, being the ordinary pay of a "Peon." The chief point, however, insisted on by the author, was the great field opened in the Isthmus, for emigration for the surplus population of this country. He contended, that it was far preferable to the Canadas, where the poor but industrious and honest mechanic, or labourer, on arriving, found that the rich lands he had heard of could only be reached by a weary journey, and after such hardships, in a severe climate, as his limited means and broken strength rendered impossible for him to bear. Australia, with its arid, trackless wastes, held out still fewer temptations to the emigrant; for the ordeal of misery to be enumerated by the majority, was such as to deter all but the stoutest hearts from encountering it. The Isthmus had none of these disadvantages. It was comparatively within an easy distance; the emigrant would be at his destination almost on landing; the resources of the country were great, and the productions varied and cheap, whilst the present population was infinitely disproportioned to the superficial area of the country. This point was strongly insisted on, and it was argued, that a grant of land might be easily obtained, in liquidation of the debt owing by the government of the country, and as the British had once possessed an establishment there in 1675 to 1690, under the charter of the "Scotch Darien Company," so a footing being again obtained, a barrier of the most formidable character would be opposed to the annexation propensities of our transatlantic brethren, who were making rapid strides towards the possession of this valuable tract.

Appended to the paper, was a copy of the commission granted to Lieut.-Colonel Lloyd, by General Bolivar, authorising his examination and survey of the Isthmus, and of the rivers, which had previously been most jealously refused to every one. This document was alluded to with some natural pride, as proving, that to an English engineer was due the merit of having been the first to examine and propose a work of such vital importance to the whole world, but which had been since claimed, and in fact, appropriated by other persons without acknowledgment.

Dec. 18.—The annual general meeting of the Institution was held on Tuesday evening, December 18th, when the following gentlemen were elected to form the Council for the ensuing year:—

William Cubitt, *President;* I. K. Brunel, J. M. Rendel, J. Simpson, and R. Stephenson, M.P., *Vice Presidents;* J. F. Bateman, G. P. Bidder, J. Cubitt, J. E. Errington, J. Fowler, C. H. Gregory, J. Locke, M.P., I. R. M'Clean, C. May, and J. Miller, *Members;* and J. Baxendale and L. Cubitt, *Associates of Council.*

The Report of the Council, which was read, alluded to the past season of unexampled depression in the engineering world, but at the same time held out hopes of improvement, on account of the agitation of the subjects of better supplies of water and gas, the sewerage and drainage of towns, the construction of abattoirs, and other sanitary questions; whilst the improvement of canals, in their struggle with the railways for the heavy traffic, the construction and amelioration of harbours, the embanking and improving of rivers, the recovery of marsh-lands from the sea, and numerous other works, which had been neglected on account of the more attractive railways, would resume their former importance, and eventually afford ample employment for the majority of the members of the profession.

It was shown, that the careful administration of the funds had been attended to, and that a considerable quantity of publications had been issued.

The alteration of the commencement of the session was shown to have worked well; and, in general, the report of the progress of the Society was very satisfactory, in spite of the bad times for engineers.

The debt contracted for the improvement of the House of the Institution was stated to have been entirely liquidated, by the liberality of a number of the members.

Telford Medals were presented to Lieut.-Colonel Harry D. Jones, R.E., Mr. R. B. Dockray, and Mr. J. T. Harrison; Council Premiums of Books to Messrs. J. T. Harrison and J. Richardson; and Telford Premiums of Books to Messrs. R. B. Grantham, T. R. Crampton, W. Brown, and C. B. Mansfield; the President addressing a few complimentary expressions to each of these gentlemen on presenting the premiums.

Memoirs were read of the following deceased members:—Messrs. J. Green, P. Rothwell, R. Sibley, and D. Wilson, Members; A. Mitchell; Lieut.-Colonel A. W. Robe, R.E.; C. K. Sibley, W. Mitchell, and J. C. Prior, Associates; and J. Woods, Graduate.

The following extract from the Memoir of Lieut.-Colonel A. W. Robe, will give a specimen of the manner in which civil engineers treat and speak of the memory of their deceased brethren, whether civil or military:—

"Lieut.-Colonel Alexander Watt Robe, R.E., was born at Woolwich, on the 31st of January, 1793; he commenced his military career, as a gentleman cadet, at Great Marlow, removing from thence to the Royal Military Academy at Woolwich, and obtained a commission in the corps of the Royal Engineers, in 1811; finally attaining the rank of Lieut.-Colonel in that distinguished corps, in 1837. By a remarkable combination of circumstances, although he was continually appointed for active service, his appearance was generally the harbinger of peace. He joined the army of the Pyrenees in 1813, just before the termination of the war in the Peninsula; and in 1814 was attached to the forces under Sir Edward Pakenham, in the expedition to New Orleans, but only arrived at the cessation of hostilities. Immediately on his return to England, he received orders to re-embark for the Netherlands, but only reached the seat of war a few days after the battle of Waterloo. He remained with the Army of Occupation until 1818, and shortly after his return was appointed to the Ordnance Trigonometrical Survey, the duties of which post he performed with great skill and ability, until 1841, when he proceeded to Halifax, Nova Scotia, as second in command of the Royal Engineers; and in 1843 was appointed Commandant of the Royal Engineers at St. John's, Newfoundland, in which command his honourable and useful career

terminated, with his valuable life, on the 2nd of April, 1849, which was shortened by disease, originating in over-exertion on the survey in the North of Scotland, and aggravated by fatigue during the great fire at St. John's, where he toiled incessantly for forty-eight hours, in protecting the lives and property of the inhabitants.

"Colonel Robe was descended from a line of ancestors who had all been in the military and naval services; his four brothers were also distinguished officers, and two of them fell gloriously in the service of their country. He was devotedly attached to scientific pursuits, and was eminently useful in promoting the object of the societies which he joined, and for this his mathematical acquirements and topographical knowledge peculiarly qualified him. He was elected an associate of this Institution in 1838, and served on the council for some years, with great zeal and attention, being continually present at the meetings, and inducing the frequent production of original papers, or presents of charts, &c., for the collection.

"In the performance of his military and civil duties, his zeal and ability were unbounded; as a son, a brother, and a friend, he could not be surpassed, and the public estimation in which he was held, was fully testified by the general mourning for his loss, at St. John's, Newfoundland, where he died, and where it was said of him that 'it seldom fell to the lot of a military man to be so beloved by civilians.' The secret of this respect and esteem was the active and untiring benevolence of his character, which was only equalled by his unassuming manner, and the frankness and mildness of his demeanour; and the highest eulogium that can be paid is, that 'those who knew him best, esteemed him most.'"

The thanks of the Institution were voted unanimously to the President, Vice-President, Members, and Associates of Council. to the Auditors, Scrutineers, and the Secretary, for their attention to the interests of this Institution.

The President returned thanks very briefly, and on retiring from the Chair, after holding it most worthily for the two past years, he recommended to the members his successor, Mr. Cubitt, whose active energy and high position in the profession, rendered him every way fit to occupy the Chair of such a society.

The address was very warmly received, and it was proposed to the council, to consider by what means the eminent past Presidents could be enabled to continue their valuable services, in conjunction with the acting council.

ROYAL SCOTTISH SOCIETY OF ARTS

Nov. 26, 1849.—THOMAS GRAINGER, Esq., President, in the Chair.

The following communications were made:—

1. At the request of the Council an Experimental Exposition was given, containing his "*Concluding observations on the 'Strength of Materials' as applicable to the construction of Cast or Wrought-Iron Bridges, and on the Conway and Britannia Tubular Bridges* (Part II.), *being an account of the method of raising the Tubes of these Bridges.*" By GEORGE BUCHANAN, Esq., F.R.S.E.

In this concluding paper Mr. Buchanan commenced by giving the result of an interesting experiment, made since the former evening, on the transverse strength of Caithness pavement. The results of the experiments already shown on slabs 9 inches broad, 3 feet deep, and 3 feet long, were as follows:—

Hailes	784 lb.
Craigleith	1148
Arbroath	1848

The Caithness pavement was rather less in dimensions than the others, being only 8¼-inches broad instead of 9 inches, and 2¾ deep in place of 3 inches. From the previous experiments on the tensile and compressive strength of Caithness pavement, he had hardly expected it would equal the Arbroath; but it was found greatly to exceed it. After piling on stones and brick to the extent of 25 cwt., the frame, being of a temporary nature, gave way, but with all the concussion the stone was not broken; and on trying it again with a stronger frame, it carried for nearly half a minute 28 cwt. 1 qr. 15 lb., and then gave way. This specimen, he understood, was from the hardest of the quarries, and he has no doubt there are considerable diversities, which shows the importance of those experiments, and of continuing and extending them with every opportunity. The unit of strength from these experiments is easily deduced by taking the breaking weight of each specimen, multiplying it by the length, and dividing by the depth and by the section of fracture. The results are as follows:—

	Units of strength.
Hailes	348 lb.
Craigleith	410*
Arbroath	821
Caithness	1500

Mr. Buchanan then proceeded to complete his description of the lifting of the Britannia Tubes.

The main process of lifting was completed previous to his visit, and the tube raised to its place; but as it still required some finishing adjustments in the bed, he had an opportunity, when there, through the kindness and attention of Mr. Clarke, of witnessing this great and interesting operation; and it was truly gratifying to observe the simplicity and perfect action of the machinery by which it was accomplished, the movement of the small engine and piston being smooth and easy, while the gigantic mass of the tube rose slowly and majestically to the place required. The ascent to the lifting machinery is first by long ladders in the dark hollow or void within the Britannia Tower. This brings us to the level of the bottom of the tube, and from thence the ascent to the top is by similar ladders in open day, resting on the sides of the tube, and, when ascended, we attain an elevation of 133 feet above high-water mark, and nearly 150 feet above low water; and in walking along the top of the tube, between the towers, there being no railing, the gusts of wind at such an elevation appear at first rather alarming, yet it is curious to remark, that immediately on the surface of the tube, and for several feet above it, a comparative calm prevails, owing to the wind impinging upon the sides and flying over head; so much so, that he was informed, even in a very strong wind, a lighted candle could be carried near the surface of the tube all the way without being extinguished.

He then illustrated the process of lifting by drawings on a large scale, and models of the Bridge and Towers, and an enlarged model of the lifting apparatus; all which exhibited very clearly the whole details of the operation. It is accomplished by hydrostatic power, worked by steam-engines, which are all erected and fixed on the top of the towers, the engines giving motion to small force-pumps by which water is forced with an intense compression into the interior of large cylinders, which again communicate this pressure with increased effect on the enlarged surface of the pistons or rams which move up and down within these cylinders, and at each ascent are capable of bearing a most enormous load resting on the top. In the Britannia Tower there are two of these cylinders and rams, standing about 8 feet apart, and carrying a vast beam of cast-iron, resting at each extremity on a shoulder on the top of the ram, and extending between them, in one solid mass, 4 feet deep, and a proportional thickness, and strengthened along the bottom by very strong malleable iron ties.

The rams being made to rise simultaneously, the whole beam rises with a slow and regular motion, bearing up whatever may be attached to it. The pressure of the water within the tubes is capable of being raised as high as 450 atmospheres, or 6,700 lb., or 3 tons and upwards per square inch; and the area of each ram, which is 18 inches diameter, being 250 inches, the combined effect of the two rams is capable of lifting upwards of 1,500 tons.

But all this machinery and power would be of no avail, unless it had a proportionally firm and secure place to stand on, and to bear up the weight of the machinery itself, and in addition to this, the 1,500 tons which it is capable of lifting. For this purpose, two very massive beams or girders, not of cast-iron, but of malleable iron, are extended across the recess or opening in the tower, resting at each extremity on strong masses of cast-iron, or wall boxes built solidly into the masonry. These beams are 21 feet long, 4 feet deep, and 18 inches thick, consisting of a mass of plates laid together and firmly bolted, and the whole, being of malleable iron, gives great additional security and confidence.

To communicate the above power of the presses to the tube, which, after being floated, is still situated 120 feet below the level of the pumps and presses, two enormous chains, consisting of long and short links of flat plates, descend from the cross beam or head which rests upon the rams, down to the extremity of the tube to which they are attached; very particular arrangements are necessary for attaching these chains to the tubes. For this purpose, the extremities of the tube are strengthened at the sides by three strong cast-iron pillars or frames, standing upright on each side of the tube, and rivetted to the thin sides of it, and connected by cross beams to the top and bottom, so as to form each one entire rectangular frame, fitting the interior of the tube. These frames are necessary, in the first instance, for strengthening the tube itself; for, strange as it may appear, though the tube carries an enormous load in the centre, yet at the extremities where it rests on the piers, and where the whole pressure is thrown and concentrated upon the thin sides, it would not, without aid, carry its own weight; it would fall to pieces in a moment by the accumulated pressure; and it was found, on the remarkable occasion of the bursting of the cylinder, though the tube only descended a few inches, such was the effect of the concussion, that these pillars and frames were fractured and shivered to pieces. It is by these frames, then, that a secure attachment is obtained for the lifting chains, and for this purpose three additional cross-beams are extended at intervals be-

* It was here suggested by Mr. Black, architect for Heriot's Hospital, that these experiments would probably not give a fair criterion of Craigleith stone, as he conceived the strength would be very much diminished by the hammering and chiselling necessary to reduce it to a 3-inch thickness, and that if the trials were made upon larger masses a greater unit of strength would, he thought, be found applicable to them. It was explained, however, that the above specimen was not from the liver rock of the quarry, but from the common rock; and, as afterwards stated by Mr. Notman, who furnished all the specimens, from what is called the pavement flakes, which run in parallel beds from 4 to 6 inches thick, the same way as the other pavements. It was 4½ inches thick when taken out of the quarry; and the reduction, Mr. Buchanan did not think could affect the strength on the above general result. The liver rock would have borne less than the specimen.

tween the top and bottom of the outside frames, and to each of these the chains are attached, so as to have a secure hold of all the three together.

Every provision and proper attachment being now made for the lifting, there is nothing to prevent the process going on. But as the rams are only capable of rising 6 feet, another arrangement still remains to be explained, and which is a curious one, and has admirably answered the purpose. Unless the rams and their cross-bearing beam had a very secure hold of the chains, nothing would be safe; and yet when the rams have ascended to the top of their stroke, they must let go this hold, otherwise nothing farther can proceed. The chains, therefore, must be detached from their hold of the bearing beams. In order to provide for this detachment, the chain, instead of being bolted or fixed to the beam, is merely passed through the centre of it, and the top of each link having a square shoulder formed upon it, two moveable or sliding blocks are laid on the top of the beam, capable of being moved by screws, more or less apart, so as to come under the shoulder of the link, and being screwed hard up, it forms a complete, and yet not a permanent, attachment for the chains. When the rams, therefore, have completed their lift, the chain is detached from its seat on the top of the beam by unscrewing these sliding blocks; but unless some farther provision were made for supporting the chain and tube—while it is detached from its bearing on the rams, the whole would fall to the ground. A second set of sliding blocks, therefore, is provided, resting on the top of the malleable iron beam, which carries the whole machinery, and the links of the chain being made exactly 6 feet in length, the lower sliding blocks are placed exactly 6 feet below the upper, so that the moment the rams have raised the chains 6 feet, it brings the shoulder of the next lower link level with the lower sliding blocks. These being then screwed together, lay hold of the chain at the bottom of the link, and keep firm hold until the blocks are detached from the top. The rams are then allowed to descend by letting off the water pressure, and having reached the bottom of the stroke, the sliding blocks then become level with the shoulder of the next link lower in succession. The upper blocks being then screwed up and the lower blocks detached, the rams again rise by the internal pressure communicated by the pumps and engine, and again carry the tube and all its appurtenances 6 feet higher, and the same operation is repeated by 6 feet lifts in succession, until the whole height is attained. When the chains ascend above the level of the rams, each link, as it rises above the level of the bearing beam, is taken down and removed out of the way by unscrewing the bolts.

The opening and shutting alternately of these blocks is all contrived ingeniously, so that the four ends of the two blocks, which have each separate movements, are yet all made to approach or recede by the turning of a single handle and pinion-winch, so as greatly to facilitate the process. On the Anglesea Tower there is only a single press, the ram being 20 inches in diameter. The single power has one advantage, that acting in the centre of the tube, this must be raised simultaneously and equally at both sides. In the double power, which possesses other advantages, there is some risk of the tube rising unequally at the sides, and turning off the perpendicular. To avoid this, an assistant is stationed at each ram, who observes on a scale, and calls out every inch as the rams ascend, and thus an equality is maintained. The opposite ends of the tubes might be lifted simultaneously by having the opposite engines and rams at work together, as was the case in the Conway; but this is liable to produce an oscillating movement in the whole tube, which it is desirable to avoid; [illegible] the lifts are made at each end alternately. As the tubes ascend at each end, care is taken to follow these up with layers or plates of timber or iron, piled up uniformly to within an inch or two of the bearing beam, so that in the event of anything going wrong, the tube would fall and rest on this packing, and do no injury.

In regard to the strength of the tube, Mr. Buchanan gave the result of some experiments, communicated by Mr. Clarke, on the strength of malleable iron. It had formerly been considered from those of Telford and Brown that malleable iron would bear 27 tons on the square inch, but these experiments were made with hydraulic or lever power, which is affected by the anomalies of friction. Clarke's experiments are not liable to this objection, [illegible] they were made by direct tension, by heaping on masses of iron or other weights till fracture took place, and from them it appeared that the average strength of malleable iron cannot be reckoned greater than 20 or 21 tons per square inch.

Some remarkable experiments were also made on rivetted plates. It had hitherto been considered, and very naturally, that the tensile strength of rivetted plates must be diminished by a quantity equal to the aggregate section of the rivet-holes, which being pierced through the metal, must, as was assumed, detract from its strength. Mr. Clarke, however, has found by careful trials, that when the bolts are put in red hot, and quickly and properly rivetted, that the contraction of the iron in cooling is such as to compress the plates together with a pressure about 5 tons to the inch, so as to require an enormous power to make the plates slide one upon another, and the heads being, moreover, so closely compacted into the plate, the bolts also resist this sliding by the power of detrusion,—in proof of which, these bolts, in cases of fracture, are often seen cut clean across as if by the shears. But whatever may be the cause, the result is, that he considers the rivetted portion of the plate as strong as the solid. These experiments, therefore, though contrary to the received notions, are highly important; they give additional confidence to the structure of the bridge, and are also extensively applicable in various cases of steam boilers and others.

He then explained particularly another remarkable circumstance in the structure of the bridge—namely, the uniting of the two great central tubes of the Britannia Tower. This was proposed to be done by inserting a small middle portion of tube in the Britannia Tower, so as, by this connecting link, to unite the two extremities of the opposite tubes in one continuous mass; and, in order to give full effect to the principle, it was proposed, before rivetting the last and final joint, to lift the extreme end of the tube resting on the land tower 12 inches or more, while the joint was making, and then let it down again to its place. The effect would be, by the two tubes pulling against one another, and distending powerfully the upper side of the tube in the Britannia Tower, that the deflection in the two opposite tubes will be diminished, and the strain, instead of being borne by the central portions of the tube, would be distributed, and shared by the whole of the section at the extremities in the Tower, where the depth is the greatest, being there 30 feet.

This was a happy idea, and he had no doubt it would be successful; it would have the effect, indeed, if all the ends were united, that though one of the central tubes were cut across at the middle, it would still hang by the extremities and sustain a very great load; and he explained particularly the nature and effect of the strains on a beam in this situation, which resembled in fact a continuous beam or flooring deal passing over several bearings or joists intermediate between the walls, or like the rails of a railway resting on its chairs. It is well known that the continuous beam is much stronger than if it were cut across at any of the intermediate joists, and the rails are subject to greater deflection in the space next the joint chairs, which, on this account, are brought closer together. Now, it is important to remark, in the case of such a beam, not merely supported at the ends, but fixed or attached longitudinally to another beam, that the whole of the particles on the upper side of the beam are not subject to a compressive force according to the general notion, but are only compressed near the centre. The extremities are subject to violent distention, and the middle parts remain neutral. The true lines of the compressive force resembled exactly that of the rafters of the roof relative to the tie-beam; and this confirmed what he had formerly explained, that the nearer we can approach, in the form of our girders, to this simple figure of a triangular frame, the more perfect would be the distribution of the tensile and compressive forces throughout the material proper for bearing them. On the whole, this arrangement would give great additional confidence in the structure of the Britannia Tubular Bridge; for, in ordinary girders, if there were any imperfection or failure in the centre, nothing could save the structure; but here we have a girder which, though it were cut through the centre, would still bear up the bridge, and any load that might be upon it, by the great strength remaining in the extremities.

Great, however, as [illegible] the strength and security of this structure, it should not be forgotten that bridges of this description, and of such enormous spans, could not be executed without great sacrifice of materials, and should not therefore be attempted, unless from absolute necessity, as in the present instance. As we increase the span, the strains on the bridge arising from its own weight and that of the passing loads must increase rapidly, owing to the nature of the transverse strain, even if there were no increase of load; and when we consider that, in addition to this, the bridge itself must be increased in all its dimensions—in length, depth, and thickness—and the passing load increased also in proportion to the length, it is evident that we must quickly approach a limit beyond which the mass of the structure will nearly overpower its strength, and leave no remnant for either load or contingency. This is shown very clearly when we compare the strength of the model tube, as shown by the experiments of Fairbairn, with those of the Conway and Britannia Bridges. The model tube weighed nearly 6 tons and carried 92½ tons in the centre before breaking, which is equivalent to 30 times its own weight equally distributed. Now, the Conway or Britannia tube, calculating from the experiments on the model tubes, and the data furnished by them, could not be expected to carry more than three or four times their own weight. As the passing load cannot, in the most extreme case, exceed one-fourth part of the weight of the bridge, there is still here an ample margin of strength and security; but yet it appears that if we were to extend our spans much farther we would rapidly approach the limit of safety.

In answer to a question from the President, he explained the mode by which provision was made to allow the tube to expand or contract by heat or cold. This was done by fixing the ends in the Britannia Tower, and causing the tube at the other bearings on the towers and abutments to rest on numerous cast-iron rollers, on which it could easily move backwards or forwards. And, in answer to a question from the Vice-President regarding the means of keeping up continuity in the rails at the extremities of the tube, he did not think any inconvenience was found from this in the Conway, and it was proposed to be provided for in the Britannia Bridge by sliding joints.

The thanks of the Society were voted to Mr. Buchanan for this interesting series of expositions on the strength of materials, which were given to him from the Chair.

2. "*Description and Drawing of a Machine for Mortising, Tenoning, Boring, and Ripping Timber,*" By Mr. WILLIAM R. DOUGLAS.

It was stated that this machine in all its parts possesses great advantage over hand-labour; and, as all the parts are useful for the trade, it is a saving

of room and framing to have them connected. The mortising is done by a fly-wheel and double-crank connected to a cross-head similar to an engine, in the centre of which is fixed the mortising-iron, the wood passing under it between two guides, the one fixed and the other elastic, to suit wood of unequal thickness. To tenon, the mortising-iron is taken out, and the frame containing the two saws is fixed to the cross-head. On the driving shaft is fixed an eccentric shove, which communicates the motion to a ratchet fixed on the end of a roller to which is fixed one end of a rope, the other is attached to a slide carriage on which the wood is conveyed to the saws or mortising-iron. To bore, a journal is put into the centre of the cross-head containing the auger, which is coupled to a square iron rod, which is made to move easily through a shove and fly-wheel placed on the top of the framing, the motion to which is communicated from a shove and fly-wheel outside the framing; any amount of pressure may be obtained by adding weight to one side of the large fly-wheel. The motion is communicated to the ripping saw by the large fly-wheel; the cross-head requires to be disconnected during the time of ripping.

3. "*On a method of introducing an abundant supply of Fresh Air into Coal-Mines, and of preventing the accumulation of Fire-Damp therein.*" By Mr. WILLIAM SHEDDEN, of Leith.

The author gives the following abstract of his method:—Fans have been long used for winnowing corn. They are used for smelting cast-iron in foundries. They are used for blowing smiths' forges. They are used by brewers and distillers for cooling their liquors. They are used for ventilating large buildings. The question occurs—could they not be efficiently used for ventilating coal-mines? Fans being of such general use, their properties are well understood. By their rapid rotatory motion they send off a large current of air from the extremity of the blades, and by which means a partial vacuum is created at the centre. Attach a pipe to this centre and let it go along the roof of all the workings in the mine—thus the enemy will be withdrawn, and a constant circulation kept up. Let another set of fans be put in motion, and pipes attached to the extremity of the fan-box, and these pipes running along the bottom of all the workings, an abundant supply of fresh and wholesome air would be thrown in, restoring the equilibrium, and making it impossible for an explosion to take place. Any one of these fans would do alone, but the two combined would be far more complete. A small engine would answer the purpose, and for the price of fuel, it might be said to be nothing at a coal-mine. I do not think it would be necessary to keep the engine in motion 24 hours in the day, perhaps 12 would be sufficient—a few hours before the miners commence work, and stop when they stop. The pipes alluded to do not require to be strong, nor their joinings to be air-tight. By not being tight they will operate along their whole length.

It is calculated that since the year 1800, more than 20,000 human beings have been killed by explosions in coal mines in this country. In 1847 and 1848, more than 1,200 lives were thus lost, and in 1849, upwards of 700.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

Dec. 3, 1849.—THOMAS BELLAMY, Esq., V.P., in the Chair.

"*On the Ancient Architecture of Scotland.*" By R. W. BILLINGS, Associate; who exhibited a large number of beautiful sketches, forming part of the illustrations of the work on the 'Baronial and Ecclesiastical Antiquities of Scotland.'

Antiquities are to be regarded not merely as objects for date-mongers, but as works of art; as memorials of ancient times, most valuable as illustrating history. The antiquarians of France and Germany—nay, we ourselves, have been too apt to claim great remoteness for their antiquities, but all these are put to shame by the more ancient remains of India and Egypt. As a preliminary remark it was to be observed, that although the principal monuments of both England and Scotland may be identical in minute details; yet, at the same time, great changes and varieties occurred in various leading features, so as to produce a distinct individuality in the character of the Scottish edifices.

The beautiful little Church of Leuchars, in Fife, by some reputed as of Saxon origin, is a fine Norman specimen, with an apsidal east end. The Cathedral at Elgin is a beautiful edifice, and the arcaded streets of that town most interesting, somewhat resembling those of Chester—the arcade, however, being on a level with the street, and constructed of stone. At three miles from Elgin is a curious old fire-proof house, at Coxton, in which the alternate stories are arched, with semi-vaultings, the upper one, however, being pointed. The turrets of Cawdor Castle, near Inverness, are curious, being circular in the lower part and octagonal above.

Mr. Billings considered the first Scotch architectural era to have ranged as in England, from 1066 to 1200. The Abbey and Palace of Dunfermline, and the Cathedral of Kirkwall, are gigantic examples of that period, and they bear a striking affinity to Durham Cathedral, the solid cylindrical columns in the two being identical; and history informs us that Malcolm the Third, in 1093, assisted in laying the foundation of Durham Cathedral, and soon after his return from that place, founded the Abbey of Dunfermline, the first monks of which were from Canterbury. The smaller Scotch buildings of the Norman period approach nearer in beauty to those of England. Among the most beautiful and perfect specimens are the Churches at Leuchars and Dalmeny. An endless variety of detail was presented in Scottish architecture, most remarkable; when not only animals and foliage were introduced, but even the signs of the Zodiac. At the period of the transition to the early Pointed or Lancet, the mouldings of the Scotch buildings became so minute, as to excite almost a feeling of pity for the workman who had to accomplish such a task. Some of the capitals at Holyrood Chapel are a verification of this—the quality of the ornament was, however, equal to the quantity. At a later period, the system became the very reverse, and more effect was produced without mouldings by the use of the chamfer, the splay of the arch however being moulded. The Cathedral of Dunblane is an extraordinary example of the great effect produced by the judicious use of limited means.

Had the ancient friendship between Scotland and England continued to exist, there is little doubt but that the architecture of both would have remained nearly identical; but the complete severance of all friendly ties between the two kingdoms, and the endless feuds among the various clans and even families of Scotland, compelled the lairds to make their houses strongholds of defence, both against their English foes, and the attacks of their own countrymen. This state of things gained for Scotland at least this advantage, that of possessing what no other country can boast of—a complete series of Castellated Architecture. Not only did the clannish constitution of society in Scotland at this time divide the population into very small parties, but the very disposition of the people was averse to large congregations; this may easily be proved by the small size of the ancient portion of Scotland's capital, and of Stirling, the approaches being defended by a strong fortress. The political changes of society have, however, gradually had their effect in Scotland, and the application of steam and machinery have almost entirely changed the state of the country in this respect. Ancient mansions have been deserted and dismantled, and detached houses of the lower classes, and many "towns," as they are called, have been allowed to decay and fall.

It is very singular that Scotland does not now possess one recognisable specimen of a Norman Castle; although, close to her borders, so many are to be found, such as Norham, Bamborough, Newcastle, and Durham. Yet, that such castles did exist, there can be but little doubt; and the only mode of accounting for their disappearance is the supposition that they were sold by the magistrates as quarries, out of which so many of her abbeys were constructed. So determined seems this desire to have been for the destruction of old castles in Scotland, that Caerlaverock is the only example earlier than 1350, and it still retains its corbelled parapet. Kildrummie, in Aberdeenshire, appears to be the first recognisable Scotch castle, and was built about 1270 to 1300, belonging to the early English style. One side is exceedingly singular, forming the end of a church with three lancet windows; probably so constructed in the expectation that any attacking force would respect the place of worship. The early Scotch castles appear to date with the time when the Bruces and Baliols left their English castles and occupied Scotch ones.

During the 14th and 15th centuries there existed a considerable affinity between the Ecclesiastical and Castellated architectural decorations, thus the hanging tracery of Rosslyn Chapel and the west front of Holyrood is found in the court-yards of Linlithgow Palace and Stirling Castle. The projecting turrets, so peculiar a feature in Scotch Castellated Architecture, are wonderfully constructed; many of them being infinitely more massive and weighty than the walls to which they are attached. This is the case at Kirkwall, where the Bishop's Palace is a fine ecclesiastical fortress residence. This edifice and the Abbey of Crossraguel are magnificent specimens. In fact, the latter is a fortified abbey, with all the requirements of a cathedral establishment.

Some of the old castles appear to have been elaborately painted in what has been called fresco; but, from the fact of the paint peeling off, it was evidently never incorporated with the plaster or wood. In their plans the castles varied considerably; and this must be attributed to the most natural of causes—the architects in those days invariably suiting their plan to the nature of the ground on which they were about to build. Caerlaverock Castle may be mentioned as one of the most singular in plan, being triangular with round towers at two of the angles, and at the third double towers with a gateway between them. This is the only fortress in Scotland retaining a moat; the portcullis room, too, is very complete. Inigo Jones is said to have imitated the plan in Longford House, Wilts, belonging to Lord Radnor. Fyvie Castle is another, quite peculiar in plan, and its elevation one of the grandest in Scotland: the centre also is highly illustrative of the Scotch Castle of the 16th century. The construction of the staircase is well worthy of notice, with its steps 16 feet long.

After the general introduction of gunnery on a large scale, by means of which the reduction of any fortress by a regular investment became only a question of time, the Scotch prudently defended their buildings against attacks by small arms, the only means that flying parties of marauders could have at command. This system was of great importance in developing architecture, for it did not prevent the addition of ornament to the Castellated house. The decorated terminations of the massive walls in some of these buildings, form a highly picturesque and pleasing contrast. It was, however, upon the old walls of keep towers, that the turrets, windows, and roofs of the domestic character are raised; and this will account for the disappearance of many of the old castles. Glammis, Castle Fraser, and others,

are striking instances of the extent to which the Turreted style prevailed through the kingdom; nearly all the old keeps receiving new tops, some of them being of a highly ornamental character.

In the early part of the 14th century was introduced another mixed style, in which the Ecclesiastical and Domestic Architecture were combined, as at Dunfermline, where the history of domestic architecture is carried back to the Norman time; for in the windows of the basement, the bold arches of Malcolm's palace surmount the windows of a later period. As the first to notice this, Mr. Billings recommended its being preserved jealously, as the only known specimen of Domestic Architecture in Scotland of the Norman period.

We now pass to the revival of the Italian styles, which, beginning about the year 1580, continued for a full century, producing numberless buildings in a style romantically picturesque, and which bear strong evidence of the architectural ability of that period. Indeed this may be called the flowery period of Scotch Architecture. The mansions may be divided into three classes of design:—1st, where the chimney-shafts, crow-steps, and open parapets appear in combination, as at Wintoun House, near Tranent; 2ndly, where a combination of turrets and square chimney-shafts exists, as at Newark; and 3rdly, where the chimneys become quite secondary, the main feature of design being high roofs with dormer windows, crow-steps and turrets. Here the court-yard of Heriot's Hospital may be cited as an example. Dalpersie, in Aberdeenshire, is the link between the castellated and domestic styles.

The Domestic Architecture of Scotland bears evidence of the great attention paid by the architects to details. Thus the window heads, and other ornaments of Heriot's work, are a complete school of design: for in that building, only one case of repetition occurs in the ornaments surmounting the windows. Indeed this edifice, as a colossal example of one date, is unequalled. Two sides of Linlithgow court-yard are of a corresponding style of architecture, the remaining two forming an interesting example of the Domestic Architecture of the 15th century. In Scotch houses the opposite sides generally present a striking contrast in style; this peculiarity is fully illustrated in an example at Newark-on-Clyde. On the river front of this building, the combination of turrets, jutting staircases, and square chimneys, is prominent: while on the court-yard side not a turret is to be seen, and the dormer window forms the main feature of the elevation. The old keep tower, to which these domestic buildings have been attached, alone enables one to recognise the fronts as belonging to the same building.

There is strong reason to believe that the original combination of jutting turrets and corbelled staircases is to be awarded to Scotland alone, in spite of what may be called foreign types. Their conical tops may possibly have arisen from the staircase or recesses called oratories, which frequently occur in street architecture of the Gothic period on the Continent, and of which there is a specimen or two also in the Cowgate, at Edinburgh. These recesses are invariably supported upon a column, whose capital is bracketed out to the required size; but the corbelled bases of the Scotch turrets belong to the early period of castellated architecture, the variety and quaintness of decoration in their windows and mouldings marking them unmistakeably as Scotch. The general picturesque appearance of the small round turrets so peculiar to Scotland, is much heightened by their contrast with the opposite forms of square massive chimney-shafts, as may be seen at Newark.

Whosoever formed the school of design which lasted during the whole of the 17th century, deserves the highest credit. Schaw, who rebuilt one of the western towers at Dunfermline, died in 1602; and although the mixture of Italian and Gothic did not predominate until the 17th century, yet many of the Aberdeenshire castles bear evidence of its advent towards the end of the 16th, and Schaw was most undoubtedly practising successfully at this time. The principal baronial buildings were built, however, after Schaw's death, and generally bear their own dates, about 1650.

An interesting fact, discovered by Mr. Billings, proves that Wintoun House, Moray House, the Great Hall at Glammis, and Craigievar Castle, are works of the same architects and builders: nearly all the plaster work of these are cut from the same moulds. As an excellent example of the architecture of the middle of the 17th century, when it became the fashion to introduce the Doric, Ionic, and Corinthian orders, surmounting one another, the body of Holyrood Palace may be cited. Although Inigo Jones has always had the credit of designing Heriot's Hospital, and his name been identified with Glammis and with one side of Linlithgow Palace, it is singular that his name never appears on the records of the building, such as contracts or bills giving minute particulars, which are still in existence. There is, however, such a strong affinity between many of that great master's works in London and some of the northern buildings, that in the absence of proof positive to the contrary, they may safely be attributed to his genius.

The elegance and variety of design in the ornamental portions of the buildings of this period must not be passed over in silence; they evince a bold and vigorous determination to accomplish something original, carrying art as far beyond the meagre Italian types as it was possible. Wintoun House may here be mentioned as standing pre-eminent in the quality of its work. The design and execution of all its detail is perfection of the style. The artistic window-heads, quite distinct from the Italian style; the elaborate geometric foliated ceilings, the chimneys and their stacks, are all equally admirable; presenting together, perhaps, the most impressive specimen of Scotch Domestic Architecture. It should be mentioned as being unique among Scotch houses in not possessing corbelled turrets. In Craigievar Castle, in Aberdeenshire, the ceilings throughout are very similar to those at Wintoun, but infinitely more varied among themselves; and even the furniture partakes of the architectural character of the building: it offers a fine example of its time (1620).

Having shown how prominent the details stood in most of the buildings mentioned, it must be observed that one of the great causes of success in the Domestic or Baronial Architecture of Scotland was the comprehensive study of situation, and the composition of designs to suit these. The jutting turrets, gables, broken forms of detached roofs and surmounting towers, and, in short, all the playfully-picturesque forms of Scotch architecture, essentially agree with its landscape, and the fitful forms of its ever-changing clouds; and is as completely in harmony with the country, as are the stately unbroken forms of Greek and Roman temples with the cloudless skies of the countries to which they belong.

After the relinquishment of regular fortification, the Scotch did not give up its external appearances, for stone cannon in hundreds of forms, as gargoyles, water-spouts, and more often as mere ornaments, are to be seen upon the more modern castles. In some of the old castles the formidable looking port-holes are on inspection found incapable of being used for working cannon, from the narrow dimensions of the walled recesses behind, there being barely room to make use of a carbine. The picturesque gateway at Linlithgow may be instanced as an example, being almost a sham armament. This innate love for fighting, which the Scotch at all times possessed, induced them to carry out their emblems of strife beyond the buildings in which they secured themselves; even the flower gardens being made to partake of a military character, as at Stirling. After the reformation had shaken the foundations of ecclesiastical domination in Scotland, it was to castles and houses that the ability of the architects were turned; and here is the golden age of Scotland's building fame. In other countries, the invention of gunpowder put an end to Castellated Architecture. It is scarcely to be doubted, that architecture in Scotland would have become more interesting, but for well-defined causes; the divided power of the monarch and the great feudal lords, and, the still more disastrous one, the English interference beginning with Edward the First.

The variety of Triforia in Scotland forms a curious feature, differing from those of England in the varied dimensions of the columns, in which must be recognised a spirit of determination to produce new effects.

The profusion of niches, also, and their elaborate details, must be considered also as a distinct feature in Scotch architecture. Bishop Kennedy's Monument, at St. Andrew's, is one of the most elaborate examples of monumental art in the world.

With regard to the Arch in Scotland, it cannot, with the exception of a few instances, be considered, as in other countries, any index to the style or date of buildings. The circular arch, only used in Norman architecture elsewhere, was always in general use north of the Tweed. A doorway of a later date than 1400, in the High-street, Edinburgh, the western door and the tower windows of Haddington, the doorway inserted in the semi-Norman wall of Holyrood Chapel, are all cases in point; their details proving them to be of a date later than their first appearance would imply. All kind of arches are common to Scotland, excepting the four-centered, peculiar to the English perpendicular; the only approach to this style out of England is to be seen in the east end of Stirling Church. It is rather than to their foliated detail of capital, bases, and mouldings, that we must look for the type of the time in which Scotch buildings were erected, and by these means the difficulty of distinction ceases. This is a remarkable feature in the Scotch architecture, a tenacity of retaining forms of styles while detail was degenerated. Thus, in Fifeshire, Dairsie Church and Michael Kirk have all the main features of early decorated buildings, and at a distance would be mistaken as belonging to that style, but the detail is decidedly debased in character, and the date upon each confirms the style from 1620 to 1630.

In the same manner that Scotch *Architects* mingled styles, Scotch *Poetical* epitaph makers adopted mixed languages; thus—

Here lies the Laird of Lundie
Sic transit gloria mundi.

Hic jacet Johannes Spends,
Qhua biggit this Kirk Yaird Dyke at his ain expenses.

England undoubtedly adopted the classical styles more readily than Scotland, and when the orders of architecture once had a hold they retained it, and our own styles became a dead letter. Scotland, on the contrary—over cautious—adopted the orders very charily, and it was not until a comparatively recent date (1660) that the three orders were seen surmounting one another in Holyrood Palace. It is to this position that the Scotch castles and houses owe much of their interest, for the architects of the time only adopted so much of the detail of Italian architecture as left the spirit of their buildings entirely Gothic.

A cordial vote of thanks was immediately passed to Mr. Billings, for his graphic sketch of the history of Scotch architecture, and for the brilliant drawings by which his remarks were illustrated.

Dec. 17.—SYDNEY SMIRKE, Esq., V.P., in the Chair.

"On the Manufacture of Glass, and its application to Architectural Purposes." By Professor DONALDSON.

After a few observations on the original introduction into Great Britain of

this useful material (for architectural purposes)—which appears to have taken place in the seventh century of the Christian era.—Mr. Donaldson proceeded to describe the different materials and their proportionate quantities as employed in making glass. He then gave a very elaborate description of the various processes connected with the manufacture of the several qualities known as flint or crystal, crown, sheet and German sheet, bottle or common green, and plate glass.—A number of drawings illustrative of each stage of the manufacture were exhibited.—Mr. Donaldson particularly alluded to the extensive use of the "rough plate glass" for roof lighting, either in the form of tiles or of "lunette domes;"—some of which were exhibited, being 5 ft. 6 in. in diameter, from the establishment of Messrs. Swinburne.—The Venetian plate, impressed with a diamond pattern, was also mentioned as a beautiful and useful article for transmitting the light without allowing objects to be seen through it.—The ventilating glass for windows, called the "patent perforated," is an admirable invention; the glass panes being perforated at regular intervals, and thus admitting air while transmitting the light. As an auxiliary to the sanitary improvement of dwellings it may prove valuable, and become generally used. In allusion to the colour acquired by plate glass on exposure to the atmosphere, Mr. Donaldson observed that some experiments by Mr. Faraday had proved the cause to be the presence of metallic oxides, which were thus influenced by the atmosphere, and imparted the blue and purple tinge so frequently observable in window panes. Some specimens of glass silvered by a new process patented by Mr. Thompson, of Berners-street, were exhibited, and a deposit of pure silver is obtained by aid of saccharine solutions. The expense of this process has been reduced within such limits as give every prospect of its adaptation to a multitude of useful and ornamental purposes. The effect of gold, bronze, steel, &c., is readily given by the application of this process to coloured glass.

A discussion arose from an objection raised by Mr. TITE as to the correctness of the term "plate" being applied to glass which was *blown*. The question is one on which much difference of opinion exists, but Mr. Swinburne contended that the term is extensively used in the trade.

Mr. C. H. SMITH offered a few observations on the practicability of cutting large squares of plate glass by the aid of a plane-edge saw and very fine sand—which he had ascertained beyond a doubt during the last summer.

SOCIETY OF ARTS, LONDON.

Nov. 28 and *Dec.* 5, 1849.—BENJAMIN ROTCH, Esq., V.P., in the Chair.

"*On the Cultivation and Manufacture of Sugar.*" By Mr. J. A. LEON.

The modern agricultural improvements, irrigation and subsoil drainage, are little known in most of the British colonies, and very few of the commonest agricultural implements have been introduced there. The chief alteration which has been adopted is the planting the canes at a greater distance from each other than formerly. The theory of clearing, planting, moulding, and cutting the cane in suitable season is understood, but seldom practised. It is erroneous to suppose that European labourers cannot endure the climate in the sugar-growing colonies, and European emigration ought to be encouraged. The first improvement in the West Indies should be the organisation of a new system better adapted for emancipated negroes. The planter of the present day cannot do better than lease his fields to a set of negroes, on condition of their planting for him three-fourths of the land with sugar-canes; so that the negroes will be dependent for support on the produce and its quality, and will not fail to cultivate the lan in a proper manner; the owner of the estate erecting improved steam-machinery, giving up the cultivation of the land, and remaining a sugar-manufacturer. The ex-planter, in his new establishment, will then no longer require hired negroes, for the people of his manufactory being British emigrants, the colonial sugar will be produced by Creole growers and European manufacturers. Small West India proprietors should join their lands, so as to form a farm of 700 or 800 acres, to be cultivated as before mentioned, and erect thereon a central sugar manufactory capable of working the produce from 500 acres of sugar-canes, which will be, on an average, 1,000 tons of Muscovado sugar from 10,000 tons of canes. Thus they would farm in a small space, and manufacture with powerful machinery, in which consists the required agricultural improvements, and isolated estates might send their concentrated saccharine matter, or crude sugar, to a parochial central factory.

The cultivation of the sugar-cane requires more labour than other plants, and in that respect a cane-field may be compared to a garden, and, like it, requires constant care and attention.

The woody part of the ripe sugar-canes is generally consumed as fuel in the process of manufacturing sugar; other portions are used as seed, forage, and manure, the green leaves being given as food to cattle. It is found that 100 lb. of canes generally yield 50 lb. of juice; these 50 lb. of juice produce by the old process of manufacture 5 lb. of Muscovado sugar and 5 lb. of molasses scum; the remainder, 40 lb., is the quantity of water to be evaporated by the manufacturing process.

Nothing can surpass the slovenly, unscientific way in which sugar is made on those estates where the common process is in use: and in the whole British dominions only four sugar plantations have received complete steam-machinery. The author recommends steam, not only as a moving power, but also for heating and evaporating purposes, and refers to a Colonial Steam Generator, which he has invented, as answering every purpose that can be required; but this modern apparatus will be only beneficial when worked on a large scale.

In selecting the ground on which a manufactory is to be erected mainly depends its future success.

The essay then describes the various existing mills made use of in the manufacture of sugar, of which the chief defects are—

1. Overspeed in motion.
2. Mismanagement in feeding.
3. Inefficiency of the moving power.

The great price of coal, however, in the West Indies, being 2*l.* 18*s.* per ton (when used), renders the working of steam-power very expensive; however, the steam may be economised and employed in subsequent processes.

The essay proceeds to describe the Steam Defecator, and other apparatus employed in the manufacture of sugar, and the advantages peculiar to each.

A great improvement in sugar manipulations, even greater than the concentration *in vacuo*, is the application of Animal Charcoal for manufacturing and refining sugar. The discovery of revivification allowing the same carbon to be used again enables the refiner to produce the best quality of sugar from the raw material by a single operation: *and by improving* on the same principle of filtration, the colonial manufacturer will succeed in producing refined sugar direct from the cane, and thereby dispense with the secondary manipulation in Europe.

Concentrated cane-juice, containing more than 50 per cent. of saccharine matter, will be altered if boiled at a high temperature, or re-concentrated at a low one; but if boiled *in vacuo*, the saccharine liquid may be rapidly concentrated at even a low temperature. The author recommends the use of Clark's Condenser, in which the steam is distributed all at once, in 216 vertical pipes, radiating to a single collecting pipe, communicating with the air-pump,—and a double-evaporation apparatus constructed by himself, and operating,

1st. Without altering the saccharine matter, as well with a minimum as a maximum of water.

2nd. Without borrowing any water.

3rd. Without requiring active superintendence, and saving fuel to a large amount.

In building a sugar manufactory, the main flue of the steam generators should pass close to the curing-house wall before reaching the chimney,—cast-iron tubes lying across the flue, having one end in the curing-house, whilst the other receives the outside air, being heated from the caloric from the furnace, warms the inner air passing from the yard into the curing-house. Thus a hot-air apparatus is formed with great economy. The direct bleaching, *i. e.* the artificial mode for separating the liquid from the solid sugar, is done by sprinkling water on the sugar with a small instrument made for that purpose; and, according to the number of ablutions, this operation will produce crushed lumps, or stamped loaf-sugar.

The modern steam apparatus for manufacturing sugar with profit requires the fulfilment of several conditions:

During crop-time, continuous work night and day,—from whence three advantages arise:

1st. The cane-juice does not become sour, as when standing during the whole night in the heated apparatus.

2nd. Fuel is saved, because the fire has not to be re-lit.

3rd. Double work being done, the expenses of the machinery are reduced 50 per cent.

A better class of labourers must be procured, and work for the whole year round provided for them.

Mr. Leon is of opinion that nothing but such a total change can restore the British sugar colonies; and to prepare for this, two things are necessary:

1st. A thorough knowledge of the modern art of building, erecting, and working the improved apparatus.

2nd. Regular theoretical and practical information on sugar manipulation for the instruction of colonial factory managers, to be given in a London laboratory, furnished with the necessary utensils for working on a small scale. The sugar for experiment should be extracted from the beet-root,—the juice of which is nearly identical with that of the sugar-cane.

The essay was accompanied with numerous drawings and models, illustrative of the apparatus and processes referred to.

Dec. 12.—T. WEBSTER, Esq., V.P., in the Chair.

"*On the Application of Electricity to the Arts and Sciences.*" By Mr. HIGHTON.

The paper was illustrated by beautiful specimens of simple and compound deposits as applied to works of art; also specimens of electrotyping, as applied to the preservation of animals, insects, and plants. A beautiful electrotype cast from a daguerreotype plate was also exhibited. Mr. Highton then alluded to the application of electricity to the art of war; to the freezing of water; to the formation of hail; to the ventilation of coal-mines; and finished by showing, that from the fact of electricity differing from all other known forces of nature in its property of producing direct circular motion, it became a most valuable analytical test for ascertaining whether certain other forces were simple and direct, acting in one straight line, or the re-

sultant of a combination of forces acting in various directions. The author concluded by applying this analytical test to the motions of the heavenly bodies.

Dec. 19.—T. UWINS, Esq., R.A., in the Chair.

Mr. HIGHTON read a short supplementary paper, "*On the Application of Electricity to the Arts and Sciences,*" when a long and interesting discussion took place, during which the various processes of electrotyping were described by Messrs. Highton, Newton, and Hunt.

A number of new specimens of electrotype were exhibited, among which was some iron tubing coated with a deposit of cadmium to prevent oxidation; also iron covered with a deposit of brass, hitherto deemed impossible—the brass being a deposit of copper and cadmium, instead of copper and zinc. The construction of chronometer balances, on which a deposit of copper on the steel remains instead of brass without fusion, and the temperature of the steel remains the same as that of the atmosphere, was also exhibited. The remaining specimens, which were of remarkable beauty, were supplied chiefly by Capt. Ibbetson, Mr. Elkington, Mr. Collis, and Mr. Ackermann; those of the last-named gentleman being from the royal manufactory at Berlin. The paper concluded with a further explanation of the philosophical part of the subject.

A paper, "*On an improved method of constructing Buildings whereby they are rendered Fire-proof, without increase of Cost,*" was read. The leading features of the proposed method are, the substitution of joists of wrought or cast iron for those of timber (generally used), and the employment of successive layers of incombustible materials, supported by these joists, and forming the finished floor or roof. The great principle of the method is the development of strength and firmness by the combination and consolidation of the whole of these materials into a compact mass. The model placed on the table illustrated the successive steps in the formation of the floors and roof; and the remainder of the building was explained by the diagrams exhibited.

INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

Dec. 11, 1849.—Lt.-Col. HARRY D. JONES, R.E., President, in the Chair.

1. A paper was read by Mr. D. GIBBONS, describing "*The Effects produced by the Action of the Sea in recent gales, upon the Piers at Kingston Harbour; also at Newcastle, in the county Down.*"

The history of the injuries caused by the action of the sea to the works of these harbours involved the consideration of two very important principles connected with harbour engineering—viz., the most suitable transverse section for sea-walls and piers; and also the depth of water at which the force of a wave, in its onward motion, would cease to prove effective, when coming in contact with sea-walls. These two subjects had engaged the consideration of other scientific societies for a long period, and much practical information was elicited, both from the account of the injuries as detailed by Mr. Gibbons, and from the very interesting discussion which ensued, and in which many members joined.

The PRESIDENT brought before the Institution the subject of "*Dover Harbour,*" and elucidated his remarks by reference to a plan prepared for the purpose. He described the original state of the harbour, and the effects produced by the motion of a pebble beach along the coast, by which, after a severe gale of wind, the mouth of the harbour was liable to be completely blockaded. The President minutely detailed the state of the harbour, as he had observed it, when he made a visit of inspection some years back, for the purpose of reporting to government the precautionary means which he might consider advisable to recommend. He also described the works at present in progress of execution, and the effects which he observed when visiting Dover this autumn as having been produced on the coast, by the construction of the groynes and pier, which was in the course of building, to arrest the progress of the beach.

2. "*On Branch Railways.*" By Mr. CHARLES BOURNE, C.E.

I hope the general importance of this subject will be deemed a sufficient apology for its introduction to the notice of the Institution. It may be assumed as self-evident, that the desire for investing money in railway speculations has been over-wrought. It is manifest that this laudable desire has been crippled, and reduced to a state of exhaustion by undue excitement. In fact, it is undeniable that vast sums of money have been injudiciously expended on railways. First of all, it is notorious that many lines of railway have been projected, and some of them partly constructed, which, probably, will never pay even their working expenses. Then, in England, the competition between different companies has led to ruinous expense. We have all heard of the "battle," or more properly the war, "of the Gauges;" which has cost the Great Western and the London and North-Western Companies such large sums of money. To such injurious stimulation, and to the prodigal expense incurred in the construction of branches and extensions, to say nothing of duplicate lines, we may attribute the present depression and stagnation. Let us, then, take warning by the errors of others, and endeavour to profit by their experience. We have to a great extent as yet escaped most of these; the object of this paper is to point out a mode of avoiding one main one. It appears to me that a grand error has been committed in having neglected the maintenance of a due proportion between main trunks and branches. In many cases, direct railway communication cannot be accomplished by main lines, and short branches on the same scale as the main lines would not be remunerative, and could not be advantageously worked; and no adequate means of overcoming these difficulties having yet been generally adopted, considerable towns are still shut out from many of the advantages of the railway system. Fortunately, however, we do not require another George Stephenson to invent a system for us. We have but to look back, and return to, and modify an old one, which in our speed we have almost forgotten. I allude to the working of railways by horse-power, which mode appears to me to be well adapted to meet the requirements of branch lines generally.

A branch to connect a town, or not unfrequently two towns, with a main line, will seldom exceed twenty miles in length—frequently not more than ten miles. In such cases the difference in time between horses and locomotives would not be important; and the means (that is the number of horses) could be adapted to the amount of traffic; whereas, if locomotive power were employed, it would be necessary always to use the engine, although probably not more than one carriageful (say twenty or thirty passengers) could ever be expected by one train. Then the fire must be kept alight all day long. Appropriate carriages being constructed, one horse, on good gradients, could draw thirty or forty passengers at a rate of ten miles an hour; of course, where stiff gradients occurred, two or more horses should be employed.

But the expense of the construction of a line would be very considerably less for horse-power than for steam; because the speed and the weight of the train being comparatively small it could at any time be readily stopped; so that public roads might be crossed on the level, thus saving the heavy expense of road-bridges, and their consequent heavy cuttings and embankments. The cuttings and fillings being thus made very light, and a single line only formed in the first instance, a hint might frequently be taken from the contractors' propensity for running into side-cuttings; so that where the embankments were of any considerable length, they might be formed, principally of the stuff taken from the boundary ditches; and this being all barrow-work, would be done at a cheap rate, and would afford much manual labour.

As to the working of the traffic the power required to move one ton on a level, on a well-made railway, is estimated variously at from six to ten pounds; we may fairly take it at 9·33 lb. or $\frac{1}{240}$th of the load. An average horse's tractive power is estimated at 150 lb., at $2\frac{1}{2}$ miles per hour for eight hours a day. Then dividing one-horse power—viz., 150 lb. by the power required to move one ton—viz., 9·33 lb., we find that one horse can draw sixteen tons, twenty miles in a day, on a level railway. But as gravity acts in direct proportion as the height of a plane is to its length, we find that in ascending a gradient of one in two hundred and forty, the power required is doubled; so that up that plane a horse could draw only one-half of what he could do on a level. But on descending the same portion of the line he would have little more to do than to keep out of the way of the carriages. On descending a sharper gradient than one in two hundred and forty the horses might ride on trucks, as the vehicles would run down by the force of gravity.

But it is not necessary to occupy the time of the Institution with these details. It may be stated, however, that locomotives not being employed, the greatest weight to be provided for would be a goods wagon, travelling at about five miles an hour, so that a much lighter rail might be used than is required on a main line. I may observe, that I have made estimates, at full prices, for the works that would be required by the parliamentary sections of three widely different branch lines in this country. For two of these the amount falls short of 2,000*l.* per mile. In the other case, where the works would unavoidably be heavy, it would not exceed 2,000 guineas per mile. But this amount does not include land or stations, or other contingencies. However, as the land would be much less injuriously severed than for main lines; as locomotives would not be used; and all desired crossings might be given, the amount of compensation for land would be materially lessened. Another thousand pounds, therefore, that is, 3,000*l.* per mile, may safely be stated as being amply sufficient money to make any branch line of railway in Ireland, including the payment for land and stations, and all necessary works.

AGRICULTURE AND ENGINEERING.*

ENGINEERING is an enterprising calling; and it had need be so, for one great field of employment—railway work—has been very much narrowed, and others must be found; until a return to common-sense on the part of the lawmakers, or a turn in the money market, again allows the prosecution of public works. At the time when the great rush was made into the engineering profession, and faculties and schools of engineering were set up, it was pointed out how wide is the scope for the application of engineering knowledge, besides the special construction of public works or machinery. In our mines, our manufactories, and the great operations of hus-

* "An Essay on the Present and Future Prospects of Farming." By William Thorold, M. Inst. C.E. London: Ridgway, 1849.

bandry, in these islands, and in our settlements abroad, it was well said there was room for many men of good training. This has been found to be so; and notwithstanding the stoppage of railway and other works, we believe there are now more engineers in permanent employment than there were five years ago.

Nevertheless, the field is still untilled; for in our mines, in our works, and in the country districts, there are not so many skilled men employed as there ought to be. This must be set down mostly to two causes—the first, that young men start with the notion of becoming resident engineers, assistant engineers, or engineers-in-chief, with very high pay; and next, and following from the first, that all their time is given to railways or machinery; and without thinking of what is wanted to be a good mine captain, manager of a factory, or country engineer. The truth is, we have too many of the silver-fork men. When there was a good start given to engineering by the railways, papas and mammas thought there was an opening to put in some of those idle young men who want the luxuries of life with as little hard work as may be. Papa was quite willing to give a thousand pounds premium to a first-rate engineer, or to pay two hundred a-year at an engineering college, if his son were to get an appointment of five hundred or eight hundred a-year. The class of people who put one son in the army, another at the bar, send one to India, and buy a living for a fourth, thought a new land of promise was opened to them,—but which has turned out a land of disappointment to many. The end is, that all are looking after one walk of the profession, leaving several others less promising, but more sure, quite unoccupied. If a young man will content himself to make, as in other professions, a small beginning, we believe that, with a little capital to help him, there is enough to be done.

The alterations in the corn laws have served more than anything to show the English the need of more scientific, and we may say more mechanical, farming. This is now very fairly acknowledged—but how is it to be done? Not by the farmers, for they are the worst taught, least teachable, and least knowing of the community. It can be done and will be done by the engineers, if the latter will bestir themselves. They have already got work under the Boards of Health and in the colonies; now they must strive to get work from the landowners.

Mr. William Thorold is a member of the Institution of Civil Engineers, but he was brought up as a Norfolk farmer; and in this strait of free trade he comes forward to help his former brethren, by showing them how much is to be done: and as the few leaves he has written are mostly of an engineering character, our readers will like to hear something of what he says. We will not trouble them with Mr. Thorold's politics, and we will not give any of our own; but to put our readers in mind how the industry of the country is neglected, and how the true end of government is lost sight of, by the factions who hold the reins of power, we will simply say that in these islands

The labour of Five Millions of people is wasted, and heavy poor-rates paid, although the country might be provided with railroads, canals, harbours, docks, piers, breakwaters, bridges, drainage, churches, and schools, and with a good house for every man, rich or poor.

Millions of acres of improvable land are left waste, because those who would improve it are not allowed to do so. Hundreds of thousands of acres of rich land might be recovered from the sea and rivers, but the government gives every hindrance.*

Manure sufficient to grow food for Five Millions of people is yearly wasted.

Speaking of the re-arrangement of farms, Mr. Thorold says—

It will then be practicable to arrange the several farms in a more contiguous and compact manner, and the buildings as near as possible being in the centre of the occupation, it will probably turn out that several fields cannot be brought into an occupation, being too far from the buildings. These can frequently be let off at a higher rent to tradesmen and others, as accommodation lands; or converted into small farms and let to deserving tenants, who by perseverance in well-doing, will ultimately become competitors for a larger one; or it may even appear more desirable to take the out-laying fields from several adjoining occupations to make an additional farm.

It can hardly be expected that this system can be carried to its fullest extent without an act of parliament being obtained to exchange lands by consent of the parties in possession, regardless of the tenure and condition under which lands may be then held. Nothing can be more easy than to take powers in that act to secure all incumbrances, settlements, &c., upon the exchanged land that existed upon the original. Powers also might be taken to borrow a limited sum of money (as has been already done by the Drainage Act) to carry out the exchange and improvements inherent thereon.

In carrying out these arrangements, the landowner will do right to have farms of different sizes, according to the extent of his estate, in order, as has been before hinted, to keep up a wholesome emulation and materials for competition, when necessary; and it should be a principle universally acted upon, that upon any farm falling into the landowner's hands, the first offer of it should be given to the most deserving and suitable tenant, then in the occupancy of another farm upon the same estate.

The next sacrifice is with regard to the timber and hedges upon the re-arranged farms. It is an essential part of the new system of farming, that trees, excepting those around the homestead, and in the boundary and fences next public roads, should all be cleared off the land; and in like manner the hedges and ditches also, except those forming the common out-fall drain of the district. The old ditches used as master drains upon wet soils, will, of course, have to remain as pipe drains of larger diameter.

It is not intended to have permanent pastures, except in particular localities, where it is obviously most profitable from the advantage that can be obtained by the frequent application of liquid manure, so as to produce two or more crops of grass in the same season; in all other circumstances, it has long been known that great injury has been sustained by both landowner and tenant, in retaining old hide-bound upland pastures, and most kinds of meadow land—whereas by a constant succession of corn and green crops, more food for cattle can be produced with the addition of a crop of corn every alternate year.

In carrying out all these arrangements, the landowner and tenant must cordially co-operate, the first supplying the capital for all permanent improvements, and the tenant paying interest upon the amount. Great care and judgment should be exercised in the execution, and they should be constantly under efficient supervision, not from any want of good intentions, but to avoid the possibility of failure. The author is sorry to say his impression goes to show that tenants with matured judgment are the exception, and not the rule.

It must also be a consideration in the first instance, whether the tenant, from his previous habits of business, not only can, but also will carry out, both the new arrangement of his farm, but likewise apply himself to the best modes of cultivation, and the application of manures to the growth of green and corn crops alternately, according to the best examples, it is presumed, he will see around him; if there is no prospect of a tenant's fulfilling all these desiderata, there is no alternative but for him to leave the estate, for "Why cumbereth he the ground?"—Landowners having quite as much right in taking the means offered for their own defence, as a party would in defending an action at law.

It is also essential in carrying out this system, as before stated, that the farm-buildings should be as near the centre of the farm as possible, which, if it cannot be obtained by exchange, addition, or reduction, the buildings necessary for occupation should be removed or built anew. The old farm-house can remain as a residence, or be converted into cottages, as may be most convenient in the preliminary stage of proceeding, and as it will frequently happen that where cottages are wanted, it will be a question whether the old farm-houses that are now on the outside of the farm, and consequently badly situated for the farmers' occupation, will not be in the most proper position for cottages? It is also necessary that good hard roads should be made, so as to approach one side of every field in all weathers, and a drift road made from the buildings to the most frequented public road.

Mr. Thorold proceeds to describe his plan for farm buildings:—

It will be impossible in an essay of this kind, to give general directions as to what buildings will be required, for in some instances, the old buildings may be made available to the new system, by means of internal alterations, and in other cases many buildings will bear the expense of removal; but by way of filling up a blank, the author has prepared a design for new farm-buildings, which is appended herewith, and as an explanation of this design will tend in some degree to elucidate part of the new system, he will proceed with the description.

The object of this design is to convert all the straw, hay, and green crops into manure, and to retain or prevent the loss of such manure after it is obtained, in the most effectual and economical manner; it is applicable to any sized farm, by merely increasing or diminishing the feeding and storing departments; but in all cases it should be limited to farms not exceeding a convenient length or breadth from the homestall, on account of the expense of road making and carriage. Steam power is intended to be applied to thrashing, dressing, grinding, and bruising corn, steaming food, cutting hay and straw into chaff, pumping water and liquid manure, slicing turnips, breaking oil cake, sawing wood, raising manure from the house by an inclined plane, to load the carts instantly, and prevent the horses waiting for the same; and probably for the purpose of exhausting foul air from the feeding houses, to excite hunger in cattle, and thereby diminish the time of fatting. It is here necessary to inform our readers, that this last plan has been adopted in factories as a principle of ventilation, and the only objection to it has been, that it makes the work-people always hungry. A very thing of all

* The Woods and Forests have lately claimed the land recovered by the Cork and Passage Railway in Cork Harbour, but without offering to pay the expense of its reclamation. It is not so long ago since they made the Corporation of Liverpool compound with them for £100,000, for land reclaimed at Birkenhead.—The recovery of 30,000 acres of land in Morecambe Bay was prevented by the Crown and Duchy of Lancaster claiming it, if recovered.

others, beneficial in grazing or fatting cattle. Provision should also be made for rendering the feeding houses perfectly dark for an hour or so after feeding time, in order that the cattle may take their rest. Cramming may thus be introduced into cattle feeding, as has long been practised with ortolans, poultry, &c.

For this purpose a portable steam-engine is preferred (with fixed barn machinery, &c.) on account of its being applicable to more than one set of buildings, which will render it less expensive, and also more adapted to meet the possible contingency of steam ploughing, and being sent to the factory to be repaired, thus avoiding the nuisance of having mechanics on their premises, or it can further be supplied by a travelling or club engine. There is the corn barn open at each end, with a railway running through it, upon which stacks are to be built upon staddle-frames running upon wheels, instead of standing as heretofore upon fixed piers or pedestals, and as many staddles are to be provided as the probable number of stacks. A stack is to be built on these staddle-frames, upon any part of the railway, and can be run into the barn at night, and remain there under cover until is thatched, which it is obvious can be done either in wet or dry weather. As soon as it is thatched, it is to be run through the barn, a sufficient distance out of the way, and another staddle-frame is to be brought empty from the cross line, and a stack built thereon as before. As soon as it is ascertained that the barn will contain the remainder of the crop, it can be filled in the usual way, and of course this last must be thrashed out first; afterwards the stacks on the staddles can be introduced into the barn, and thrashed by a like process. The length of railway will be limited by the locality and expense, but it must be of sufficient length to admit of two or more kinds of corn being stationed on either side, so that any particular stack can be thrashed when wanted, by running all those before out of the way; as it is intended to have the rails perfectly level, but little power will be required to do this. Hay stacks may also be stationed on close boarded staddles at one end of the line, and can afterwards be brought into the barn when they are required to feed the hay cutter, being thus under cover during the time it would otherwise be partially exposed to the weather.

THE WATER MONOPOLY AND THE SANITARY MOVEMENT.

The subject of the water monopoly is now attracting so much attention as to induce the *Times* to devote to it its valuable columns, and the following forms part of a series of excellent articles, evidently from a man of knowledge and ability:—

In the year 1580 Peter Morrys, a Dutchman, came to the Lord Mayor of London, and declared himself the inventor of a plan for making the Thames water, by its own force, flow upward to the tops of the highest houses in the city. The supply of water being at that time excessively scanty, and the population rapidly augmenting, permission was granted to this daring schemer to try his experiment at his own risk. He stipulated for a lease of the first arch on the north side of old London-bridge, which was granted to him for 500 years, at a nominal rent of 10s. per annum, and he proceeded forthwith to erect his machinery. He set to work with such vigour that, a few months afterwards, the inhabitants of that part of the town were astonished one day to see a column of water rising into the air, and thrown completely over the steeple of St. Magnus Church. The lord mayor and aldermen came down to witness this experiment, the like of which had never before been known in England. The pipes of elmwood laid along Thames-street, Fish-street-hill, and Gracechurch-street, with their valves to prevent the reflux of the up-forced water, and their small leaden branches ramifying to the houses on either side, came in for a full share of admiration; and it would be difficult to exaggerate the joy of the fortunate householders in that neighbourhood at finding the water, which they had been accustomed toilsomely to fetch from the Wall-brook hard by, or to draw up with bucket and windlass from wells, now gushing spontaneously into their abodes, and let in or shut off as required, by the mere turning of a stopcock. We gather from ancient records of William the Conqueror's time, that the London water-sources of that period were, the Thames on the south, the suburban fountains on the north, such as Clerk's-well, Holy-well, Clement's-well, &c.; and in the heart of the city several brooks and bourns which rose from those fountains and ran southward to the Thames—the Wall-brook, for instance, the Long-bourn, the Old-bourn, and the Rivulet of the Wells; to which springs and streams the Londoners then resorted after the fashion of simple villagers, with pail and pitcher for their supplies.

The artificial conduit system appears to have originated in London towards the middle of the 13th century. For, in 1235, when the encroachment of buildings and the heightening of the ground had spoiled or dried up these fountains and rivulets, causing a dearth of water, while the rapid growth of the population still further increased, we find the Lord Mayor and Commonalty, at the request of King Henry III., engaged in bringing fresh supplies to the city from the town of Tyburn by six-inch pipes of lead, and setting about the erection of a great stone cistern, lined with lead and handsomely castellated, for the public use, in Westcheap. This, the "Great Conduit," as it was called, was the first of its kind in London, and its tedious and expensive construction occupied 50 years. The pipes from this watercourse were subsequently extended eastward, to supply other cisterns which were established successively in Fleet-street, Aldermanbury, and at divers other points of the town. As the population outgrew these supplies, the springs of Highbury (1438), Paddington (1439), Hackney (1535), and Hampstead (1589), were successively laid under contribution, and brought in earthen pipes, "brick drains," or tubes of lead, to the several standards or conduits, as they were called, in Oldborne (Holborn), Eoldgate (Aldgate), Cripplegate, Bishopsgate, &c.

These particulars give some idea of the solicitude felt from the earliest times to secure a good water supply for the metropolis. And, if we picture the water-carriers, stooping at the river side, clustered round the public tank, or bearing away on head or shoulder their replenished tankards—wide-bottomed, narrow-mouthed vessels, hooped like a pail, and fitted with a cork or bung—we shall have a tolerably complete notion of the ancient London water service.

The conservancy customs of those early times are vividly pictured by Maitland, who describes the mayor and aldermen riding forth on horseback, with their ladies following in wagons, to take their annual survey of the conduits; after which they used to hunt the hare across the neighbouring fields, then dine with the chamberlain; after dinner go to hunting the fox; and after "great hallooing at his death, and blowing of hornes," ride back through London to the Mansion-house.

The invention of the lift-pump (in 1425) might have been expected, by facilitating the raising of water, to improve in some degree the semi-barbarous state of the city. But the pump shared the common fate of useful inventions, always slow,—and especially slow in those days—to win popular acceptance; and, moreover, the cost of setting up an engine, then reckoned so rare and intricate, operated as a further hindrance to its general introduction.

The success of his first water-wheel, which raised 216 gallons of water per minute, induced Morrys to apply for a lease of the second arch of the bridge, which was immediately granted by the corporation on the same prodigal terms as the first. Beneath this arch Morrys proceeded to erect a second set of pumps and cisterns, with another water-wheel, by which means, 1584, he more than doubled his first supply. Our enterprising Dutchman, however, did not remain long without competitors. Within ten years after Morrys set up his first wheel, one Bevis Bulmar erected a large horse engine at Broken Wharf, in the city, and raised water through leaden conduit-pipes for the supply of Cheapside, St. Paul's Churchyard, and the parts adjacent, as far westward as Fleet-street. Animal power had previously been employed by the corporation to pump water to a standard on Dowgate-hill; but this mode of pumping proved too costly to be compatible with moderate rates, and Bulmar, like several similar speculators on a smaller scale, was ultimately ousted by the powerful competitor who next appeared in the field.

This was no other than the famous Sir Hugh Myddelton, a London goldsmith, who, having enriched himself by fortunate mining speculations in Wales, was emboldened by foregone success to adventure on novel hazards. The project was, to cut a trench or watercourse large enough for the supply of all London to any suitable spring that might be found within a circuit of 20 or 30 miles round the city.

The conception, grand as it was, did not exceed the grievous necessities of the time. For, the water supplied by Morrys from the Thames, besides being limited in quantity, was often exceedingly turbid and foul; and the unspeakable squalor of the poor occasioned well-grounded apprehensions that the plague, in those days a frequent sojourner in London, would renew its dreaded visitation. Moved by such considerations, the corporation had already, towards the end of Elizabeth's reign, obtained power from parliament to cut a river for conveying water to the city from any part of Middlesex or Hertfordshire. This done, they had rested on their oars, with true corporate procrastination, for six or seven years,—till, suddenly, in 1603, the plague broke out, and raged with such virulence that in one week it carried off upwards of 1,000 persons in the metropolis. Thus fearfully admonished, the corporation sent surveyors to examine where water might be procured; and having, after much delay, fixed on the springs of Amwell and Chadwell in Hertfordshire, 20 miles north of London, as sufficiently copious and pure for their purpose, they obtained in 1606-7 a new act, authorising the conveyance of these waters by an aqueduct to the city. Then followed two more years of vacillating delay; and at length, in 1609, their courage failing them after all, they made over to Myddelton, at his instance, their power to construct the New River, together with any profit that might accrue from the enterprise.

Myddelton immediately set to work, and soon found that he had undertaken a very tough job. The undulations of the ground obliged our projector, for the even distribution of the fall, to give his channel a devious and meandering course, nearly doubling the crow-flight estimation of its length, and the computed cost of the work; so that by the time Myddelton had brought it to Enfield—just about half-way to London—his progress was stopped by exhaustion of funds. The corporation, to whom in his exigency Myddelton applied for assistance, met him with a direct refusal: and King James I., to whom he next applied, declined, with characteristic rapacity, to afford him aid except on condition that a moiety of the concern should be made over to him for his exclusive profit and emolument. To these hard terms Myddelton perforce acceded; and, resuming his operations with his wonted energy, finally completed the work in 1613, twelve months before the expiration of the term allotted by the corporation for its achievement.

Estimating on the most liberal scale, the cost of timber, lead, and bricks, for the raised troughs, the reservoirs, &c., and making ample allowance for contingencies, we shall scarcely arrive at a larger sum than 150,000*l*.* as the probable total expenditure up to Michaelmas Day, 1613;—when the water first flowed into the New River head, 85 feet above the mid tide level of the Thames.

Myddelton was now overwhelmed with laudations. He, however, being a shrewd, practical man, with a clear eye for the main chance, proceeded to retrieve his fortune by dividing his moiety of the concern into 36 shares, of which he sold about half, so as to replace, in part at least, his adventured capital. He then, in conjunction with his new partners, set about laying down wooden pipes through the town for the distribution of the water, which he shortly after began supplying to the inhabitants at an annual charge of about 1*l*. 6*s*. 8*d*. per house. As several thousands sterling per annum must have been thus received from the outset, and nothing was divided for 20 years, we may suppose that the excess of receipts, after paying cost of maintenance and interest of loans, was applied in extending the pipes. In 1619 the concern was incorporated by royal charter as the New River Company, with Myddelton as its first governor. Myddelton, however, who mistrusted the notorious selfishness and rapacity of his royal associate, contrived, with great sagacity, to exclude him from any share in the management.

For nearly a century the New River Company had the metropolitan water trade almost entirely to themselves. Morrys, indeed, continued to pump up and sell the feculent water of the Thames; and two small works, one at Shadwell (1660), the other at York-buildings, Villiers-street, Strand (1691), were also set up in the same trade. But both these latter establishments were ultimately beaten by their stronger rivals; and the York-buildings Company, in particular, was broken up by the competition of the New River Company, who, having ruined them, took possession of their district, buying only such portions of the plant as suited their purpose, and leaving the rest, an uncompensated loss, on the ousted company's hands.

During the earlier part of their career the dividends of the water traders were kept down by the frequent fracture and constant leakage of their pipes. These, being of wood, were of so small a bore that eight or nine collateral trains were required where now one capacious main is laid. One-fourth of the whole water supply leaked through them, converting the ground of London into an artificial swamp; and the discovery of one broken pipe would often involve 20*l*. or 30*l*. worth of digging and search. Notwithstanding these difficulties, however, we find the New River shareholders receiving, in 1663, 15*l*. 3*s*. 3*d*. per share on 72 shares, on which probably (by the foregoing estimate) from 1,500*l*. to 2,000*l*. each had been subscribed. From this time the profits increased rapidly; and Myddelton, finding this very shrewdly proposed to the needy and prodigal Charles to buy back the shares which his royal predecessor had acquired. King Charles willingly gave up his 36 shares for an annuity of 500*l*. a year; being probably between ⅔ and 1 per cent. on the capital which they represented. In 1680 each New River share is stated to have produced a net dividend of 145*l*.; so that, on the re-acquired Crown shares alone, the company at that period must have netted a balance of 4,720*l*. per annum clear profit. An unlucky mischance having destroyed the company's ancient records, we are left very much in the dark as to their original outlay and gains. But the returns of their modern expenditure on pipes and machinery, if pared down to a reasonable valuation, show a total probable outlay of capital of from 500,000*l*. to 750,000*l*., at the utmost; or from 7,000*l*. to 10,000*l*. for each of the shares which now nominally represent and sell for about double the mean of those two sums. Even of this capital, a large proportion has, in reality, been contributed in the shape of excessive water-rates by the public.

The public water-service was gradually let slip by the corporation of London during the 17th century; and, little by little, yielded up to chance and private speculation. Many of the conduits, for example, which were damaged or destroyed by the great fire in 1666, were left to their fate; the melted pipes remaining unrepaired, and the tank-houses in ruin or demolished; so that a writer of the time bewails the hard case of the poor tankard-bearers, whose trade the conflagration had destroyed, "making them like to perish by fire who were wont to live by water." In 1692 the Hampstead waters, with the reservoirs which a century before had been built, at the public cost, for their reception, were given up by the corporation to some private individuals who, having obtained a charter, formed the germ of the present Hampstead Water Company; and a few years later (1701), the corporation let out the "Maribone" water, and several other conduit waters, to one Soams, a speculative goldsmith, reserving only a proportion of the supply for the use of the prisons and compters.

It was in the same year that the family of Peter Morrys, after having struggled on for nearly a century against the New River Company, was obliged at length to give up the contest; and it was to the above-mentioned Soams that they sold off their lease and plant for 38,000*l*. Soams seems to have made a good bargain; for he resold the concern to a company for 150,000*l*. in 300 shares. To this company, with are eklessness now become habitual, the corporation granted three more arches of the bridge, on leases, like the former, equivalent to perpetuity; which leases the city was obliged to redeem at a heavy cost to the public, when it became necessary to pull down old London-bridge and to remove the water-wheels beneath it.

A few years later, London having in the meanwhile rapidly extended westward, the Chelsea Company was established (1723), to supply a large district which lay beyond the range of the New River Company's pipes.

Soon afterwards the populous district south of the Thames—in itself a great city—attracted the notice of the water speculators. In 1756, the germ of the present Southwark Company was set up; and in 1785 a few private individuals commenced, on a very humble scale, the now powerful and lucrative concern known as the Lambeth Waterworks.

These five companies, three on the north of the Thames, and two on the south, possessed, until about the year 1805, the whole water trade of the metropolis.* Each enjoyed an effective, though not a legal, monopoly in its own district; and of their profits some notion may be formed from the fact that the Lambeth Company, which started with a capital of only 5,920*l*., in 32 shares of 185*l*. each, obtained water-rents of such amount as enabled them in 33 years to invest, out of profits, 130,000*l*. in the extension of their works, *besides* paying dividends of 50 to 100 per cent. and upwards on the subscribed capital.†

To this palmy condition of the water companies the introduction of steam power into the water service had not a little contributed. This improvement, which we have adopted as marking the fourth epoch of our London water-history, dates from 1782, when the Chelsea Company substituted one of Boulton and Watt's condensing engines for the tidal wheel which had previously worked their pumps. Five years afterwards (1787) the New River Company, who had before employed, first a windmill, and then a horse-engine, to impel the water through the upper levels of their district, also set up a steam-engine on Watt's condensing principle. Even the old London-bridge Company erected a steam-engine to aid their water-wheels at low tides; and the three southern companies likewise found it their interest to adopt the same rapid and economical means of pumping.‡

One invention involves another. The old wooden pipes, which required renewal every 14 or 15 years, and were always leaking at the joints, soon proved inadequate to sustain the increased pressure of the higher level to which the water was raised by means of the new steam pumps. Hence the gradual adoption about this period of iron pipes, which were laid down in place of the wooden ones as these latter successively wore out. In this metal mains of 3 feet diameter, it was found, could be easily cast; and the vast columns of water thus conveyed took up less space under the roadway, caused less leakage, and required less frequent repairs, than half the streams conveyed tin the clumsy hollow trunks before employed. Iron pipes have their inconveniences, no doubt; amongst which may be mentioned that they appear apter than wood to accumulate, in the form of adherent incrustations, the chalky deposit of the water; so that in 20 years a 5-inch pipe has been found reduced to a 3-inch capacity; and in 50 or 60 years it may probably become necessary to incur the cost of taking it up, in order to remove this obstruction. The tenacity of the newly-adopted material, however, being such as to withstand with ease a pressure of 300 feet of water, facilitated the introduction of a third great improvement—viz., the high service. This fell in, happily enough, at the beginning of the present century, with the gradual introduction of closets requiring elevated cisterns for their supply. To the companies it proved highly advantageous, as affording them a pretext for adding 50 per cent. to their rates.

In 1805, however, an unexpected storm broke in upon their prosperous career. A water mania, like our recent railway mania, began at that period to spring up; and on its sudden outbreak in 1810 the principle of competition, to which the legislature had all along looked for the protection of the public, was put upon its trial. Two powerful companies, which had been several years occupied in obtaining their acts and setting up their machinery, now took the field: one, the West Middlesex, attacking the old monopolists on their western flank; the other, the East London, invading their territory from the opposite quarter. A the same time a band of dashing Manchester speculators started the Grand Junction Company with a flaming prospectus; and boldly flung their pipes into the very thick of the tangled network, which now spread in every direction beneath the pavement of the hotly contested streets.

These Grand Junction men quite astonished the town by the magnificence of their promises. "Copious streams" of water derived, by the medium of the Grand Junction Canal, from the rivers Colne and Brent,—"always pure and fresh, because always coming in"—"high service, free of extra charge"—above all, "*unintermittent supply, so that customers may do without cisterns;*"—such were a few of the seductive allurements held out by these interlopers to tempt deserters from the enemy's camp.

* A watercourse of the dimensions of the New River is, we are informed, at this moment in course of execution in Holland, at a charge of 2,500*l*. per mile; at which rate the cost of the New River (39 miles long) would be only 97,500*l*.

* We pass over as insignificant three or four minor establishments no longer in existence, such as the small works at West-Ham, Shadwell, Rotherhithe, Bank-End, and Hackney. We also leave out of the account the Hampstead Company, which supplies spring water from Hampstead-hill to part of Kentish and Camden towns; the Kent works, which supply water from the river Ravensbourne to part of Deptford, Woolwich, Greenwich, and Rotherhithe; and the Paddington springs, which belong to the Bishop of London's estate, and supply the inhabitants of the immediate vicinity.

† The aggregate dividends received by the Lambeth shareholders during 16 years ending 1848, amounted to 66,400*l*., or eleven times the amount of their original subscription. Of these 16 years the 11 earliest also form part of the 33 years (ending 1828) during which the vast capitalisation of the revenue mentioned in the text took place.

‡ The old steam-engines of Savery and Newcomen, in which the cylinder itself was cooled at each stroke of the piston, had been tried so far back as the beginning of last century by the York-buildings Company.

Meanwhile the South London (or Vauxhall) Company was started (in 1805) on the other side of the river, with a view to wrest from its old rulers the watery dominion of the South. The war was not, however, carried on in a very royal sort; for, as the travelling mountebank drives six-in-hand through a country town to entice the gaping provincials to his booth, so these water jugglers went round the streets of London, throwing up rival *jets d'eaux* from their mains, to prove the alleged superiority of their engines, and to captivate the fancy of hesitating customers.

The New River Company, thus put upon its mettle, boldly took up the gauntlet. It erected new forcing engines, changed its remaining wooden pipes for iron, more than doubled its consumption of coals, reduced its charges, augmented its supplies, issued a contemptuous rejoinder to its adversaries, and, appealing as an "old servant" to the public for support, engaged in a war of extermination.

For seven years the battle raged incessantly. The combatants sought (and openly avowed it), not their own profit, but their rivals' ruin. Tenants were taken on almost any terms. Plumbers were bribed to tout, like omnibus cads, for custom. Such was the rage for mere numerical conquest, that a line of pipes would be often driven down a long street to serve one new customer at the end. Arrears remained uncollected, lest offence should be given and influence impaired. Capricious tenants amused themselves by changing from one main to another, as they might taste this or that tap of beer. The more credulous citizens, relying on the good faith of the "public servants" (as these once powerful water-lords now humbly call themselves), were simpletons enough, on the strength of their promises, to abandon their wells, to sell off their force-pumps, and to erect waterclosets or baths on the upper stories of their houses. In many streets there were three lines of water-pipes laid down, involving triple leakage, triple interest on capital, triple administrative charges, triple pumping and storage costs, and a triple army of turncocks—the whole affording a less effective supply than would have resulted from a single well ordered service. In this desperate struggle vast sums of money were sunk. The recently established companies worked at a ruinous loss; and such as kept up a show of prosperity were in fact, like the East London Company, paying dividends out of capital. The New River Company's dividends went down from 500*l.* to 23*l.* per share per annum. In the border-line districts, where the fiercest conflicts took place, the inhabitants sided with one or other of the contending parties. Some noted with delight the humbled tone of the old arbitrary monopolists, and heartily backed the invaders. Some quiet old stagers stuck to the ancient companies, and to the faces of familiar turncocks. These paid; but many shrewd fellows put off the obsequious collectors, and contrived to live water-rate free. Thus the honest, as usual, paid for the knaves; and the ultimate burden of all these squandered resources fell (also as usual) on society at large.

Such a state of things could not last; and in 1817, the great water companies coalesced against the public; and coolly portioned-out London between them. Their treatment, on this occasion, of the tenants so lately flattered and cajoled, will never be effaced from the public memory. Batches of customers were handed over by one water company to another, not merely without their consent, but without even the civility of a notice. Old tenants of the New River Company, who had taken their water for years, and been their thick and thin supporters through the battle, found themselves ungratefully turned over—without previous explanation—to drink the "puddle" supplied by the Grand Junction Company. The abated rates were immediately raised, not merely to the former amount, but to charges from 25 to 400 per cent. more than they had been before the competition. The solemnly promised high service was suppressed, or made the pretext for a heavy extra charge. Many people had to regret "selling their force-pumps as old lead," or fixing waterclosets on their upper floors on the faith of these treacherous contractors. Those who had fitted up their houses with pipes, in reliance on the guarantee of "*unintermitting pressure*" found themselves obliged, either to sacrifice the first outlay, or to expend on cisterns and their appendages further sums, varying from 10*l.* or 20*l.* up to 50*l.*, and even in many cases, 100*l.* When tenants, thus unhandsomely dealt by, expressed their indignation and demanded redress, they were "jocosely" reminded by smiling secretaries, that the competition was over, and that those who were dissatisfied with the companies' supplies were quite at liberty to set up pumps of their own.

Flesh and blood could not long endure such exasperating treatment. The murmurs of the public, after continuing to increase during three years, broke out at last in a storm of indignation; and in 1821 the first of a series of parliamentary investigations took place. The committee of the House of Commons which conducted this inquiry, addressed themselves chiefly to the financial branch of the subject. They called for returns, examined engineers and secretaries, as well as aggrieved tenants, and brought to light innumerable instances of injustice. Amongst other examples of arbitrary conduct on the part of these monopolists, it came out that they would frequently refuse water to a whole street of new houses; declining, when applied to, to run a service-pipe along it, even though their main passed the end of the street. And thus builders, in order to avoid having their houses on hand tenantless, were constrained to lay down pipes at their own cost; and then come humbly, cap in hand, to the company, to beg a supply at the ordinary rates.

The inquiry ensued a report (dated 1821) which deprecated the irresponsibility of these companies, and recommended a legislative restriction of their rates. Acting on this hint, Mr. Michael Angelo Taylor brought in his well known bill to restrict the water companies from increasing their rates to more than 25 per cent. beyond the rates of 1810. This bill passed the House of Commons, but was lost in a committee of the House of Lords by a majority of one. In the meantime the public attention had taken another direction; and the companies, finding the storm passed by, became bolder and more arbitrary than ever.

During this period the memorable bubble-fever of 1824-5 took place; and, as on a more recent occasion, the "earth had bubbles," so at that time had also the water,—in the shape of various brilliant schemes for bringing rivers to London by mighty aqueducts, and stupendous tunnels.

Suddenly, however, in 1827, a pamphlet appeared which threw the whole town into a state of consternation. This pamphlet, which was called the *Dolphin*, originated, as its author declared, in the deathbed repentance of one Robson, a director of the Grand Junction Company; who, to use his own expression, "*feared God would never forgive him*" for having been party to the wronging of 7,000 families by the false promise of good water, and the cruel service of poisonous filth; and who, shortly before his death, to ease his conscience, divulged the enormities in which he had taken part to Mr. Wright (the pamphleteer), with an earnest request that he would by every means in his power seek legislative reparation of the fearful wrong inflicted on the public. This strangely originated document disclosed the secret abominations of the water trade; especially dwelling on the fact, that the Grand Junction "Dolphin" or suction pipe, lay exactly opposite the great Ranelagh sewer, *and only three yards from its mouth at low water!* The tract was eagerly bought up, and caused an excitement so intense that subscriptions amounting to upwards of 300*l.* were readily entered into for promoting its circulation. A public meeting was convened under the auspices of Sir F. Burdett, and all classes of society, from the highest peers of the realm down to the humblest shopkeepers, eagerly attended it. In the next session (1828) a scientific commission was accordingly appointed to institute the requisite investigations.

The facts elicited in the course of this inquiry were perfectly astounding. The New River Company, which was the first examined, was driven to admit that its principal reservoir had not been cleaned for 100 years; and that, when at last the water was run off, *eight feet of mud were found at the bottom!* It appeared that their pretended spring water was eked out by supplies, not merely from the river Lea, polluted by the sewage of Hertford, but also, to the extent of 300,000 hogsheads and upwards annually, from the Thames, between the mouths of the Fleet-ditch and the great Walbrook-sewer. To crown all, it came out that *Myddleton's aqueduct itself* had, by the neglect of the company for 200 years past, degenerated into a "common ditch," receiving the surface waters of the manured fields and the sewage of the populous villages through which it passed—an abomination which, having become a "vested interest," continues, we believe, to this day, in spite of the company's tardy and ineffectual remonstrance. It was further alleged that in consequence of their exorbitant charges for water, road-trustees had been driven to employ sewer-water for watering the streets! One witness stated that on being remonstrated with for leaving their water-plugs uncovered, so that ponies and donkies put their legs in the holes and were maimed, the company's officers declined to abate the nuisance, declaring it "cheaper to pay for the breaking of a donkey's leg now and then, than to incur the cost of putting covers to the plugs."

Finally, after weighing all the evidence, the commissioners produced a very able report, recognizing the insalubrity of the existing supplies, and the necessity of seeking purer sources.

In accordance with these recommendations, and at the instance and cost of Sir F. Burdett, the Lords of the Treasury shortly afterwards directed Mr. Telford, the engineer, to survey the country round London, with a view to discover the springs and streams most available for the supply of London, and to report on the means of conveying their waters to the metropolis. These researches having been set on foot, the public excitement again died away; and another six years' lull ensued.

The damaging disclosures which had resulted from the parliamentary inquiry of 1828, and the strongly expressed dissatisfaction of the public, at length aroused the fears of the water companies; who at this period appear to have been seriously alarmed as to the permanence of their misused privileges.

Accordingly, in 1829, the Chelsea Company began to send out filtered water; and in the following year the New River Company formed two settling reservoirs near Stoke Newington, with a view to purify by subsidence their drain-infected stream.

These improvements, though their empirical adoption under the influence of the "pressure from without" reflects small credit on the water monopolists, were, nevertheless, a very real and important step in advance. They were regarded by their introducers (and even by the parliamentary commissioners of 1828) as merely *mechanical* contrivances for the removal of sediment; but, when properly understood and practised, they are, as we shall hereafter have occasion to show, in a great measure *chymical* processes; and the date of their adoption opens an entirely new epoch of our metropolitan water-history. This, the fifth, or chymical period, is still in its infancy; and, though our present business is rather to record than to suggest improvements, we may perhaps venture, in defining the characters of this period, to indicate also the probable course of its future development. In the meantime we are bound to record, to the indelible disgrace

of the London water companies, that filtration, to which they had only partially resorted in or about the year 1820, was in full operation many years previously at Manchester for the supply of pure water to the cotton manufacturers; of whose filters, in fact, those subsequently established on the banks of the Thames were but imitations at second-hand.

The example thus set was followed by several of the other companies; those, for instance, whose sources of water were the foulest and worst, began to think of extending their suction pipes to less objectionable quarters. Thus, the East London Company, which had previously pumped, at flood tide, from a point of the Lea so near its mouth, that the water obtained was in fact the turbid influx of the Thames itself, now brought their water by a canal three miles long from a place above the influence of the tide. The South London, following the example of the Chelsea, began to filter their drain-polluted water through beds of gravel and sand; and several other companies adopted, or discussed, similar partial measures of improvement. As for the Grand Junction directors—who had, from the first, been distinguished for the splendour of their promises—they gave out that they had in view a scheme of almost Roman grandeur. This dazzling proposal was to bring the water of the Colne to London by a canal twenty-five feet wide, with several tunnels and colossal aqueducts (of which latter, one was to be as high and three times as long as Blackfriars-bridge) and to undertake, by this means, the supply of water to the whole metropolis! This scheme was the revival of one originally proposed in 1719, during the South-Sea-bubble mania; and which, after being three times reproduced in the last century, and three times more in the present, by a series of more or less visionary projectors, was adopted by the Grand Junction Company. The directors introduced their bill into parliament; and were, of course, stopped by a resolution of the house to await the result of Mr. Telford's survey. It need hardly be added that the project was subsequently abandoned.

Suddenly, in the midst of these dilatory proceedings, the cholera morbus of 1832 broke out, and public attention in the metropolis was again drawn to the defective state of the water supply.

The Asiatic plague had not yet entirely subsided, when a new water committee was appointed to receive and consider Mr. Telford's scheme, and to examine generally the remedial branch of the question. As the two previous committees had reported respectively on the price, and on the quality of the water actually sold in London, so the business of the present committee was to investigate the relative feasibility of the various projects for improving, in both these respects, the future supply of the metropolis. This committee produced no report; but the minutes of evidence taken before them filled a large blue book, dated 1834.

It would be difficult to determine which of the various engineers examined cut the sorriest figure. Mr. Telford's assistant, Mr. Mills, charged his employer with filching his ideas; and the illustrious constructor of the Menai-bridge seems certainly, on this occasion, to have looked through his colleague's eyes somewhat more than he was willing to confess.

The plan was to form two aqueducts: one for the supply of London north of the Thames, the other for the service of the southern metropolitan districts. The northern aqueduct, 16 miles long, was to bring water from the Verulam, near Watford, at the rate of 30 cubic feet per second (about double the actual consumption of the northern districts); the southern aqueduct, 6 miles long, was to convey water from the Wandle, near Beddington, at the rate of 13 cubic feet per second—the actual consumption of the metropolis south of the Thames being then about 6½ cubic feet per second. The northern reservoir was to be on Primrose-hill, 146 feet above high water in the Thames; the southern one on Clapham-common, at a level of 80 feet above high water mark. The cost, including compensation to millers, was to be 785,965*l.* for the northern, and 391,875*l.* for the southern works. These works were to be executed at the public cost by government, who were to raise the money by loan, and to deliver the water into the pipes of the several companies, charging them interest on the capital expended, and leaving to them its retail distribution through the town.

Altogether the result of this third inquiry was negative. The need of improvement was clearer than ever, but the means of effecting it seemed proportionably more doubtful than before. The clashing opinions of the rival engineers showed on how empirical a basis our water system had grown up; and the bold pretensions of the chartered companies afforded a new proof how firmly corporate privileges, once conceded, take root; and how difficult it becomes, in the process of time, to correct the evil consequences of past legislative errors.

One point, however, was very clearly made out—viz., that notwithstanding the inertial resistance thus opposed by some companies to the public demand for progress, and the narrowness of the concessions which even the most liberal of them reluctantly made, the collective metropolitan water-rents had increased since the last return in 1821 no less than 79,054*l.* a-year, an augmentation equivalent, at 5 per cent., to an expenditure in fixed capital by the companies of 1,581,000*l.* sterling; whereas 300,000*l.* only, or less than a fifth of the due proportion, had actually been laid out on extension of "plant" within the same period. Nor was this all. The added capital, thus virtually producing upwards of 26 per cent. per annum profit to the companies, had been mainly provided by the application of surplus revenues; or, in other words, had been extracted from the pockets of the public; against whom, nevertheless, this very outlay was now reckoned as a reason for maintaining the monopoly rates. 729,885*l.* was the vast total of capitalised plunder confessed to, in 1834, by six of the eight great companies,—the two others (the Southwark and the New River) setting down their plunder at zero.

The West Middlesex Company, in like manner, returned their "real capital embarked" as 568,045*l.*—a purely nominal and fictitious amount, eked out by the monstrous charge of 163,712*l.* as the interest which their plant *should* have produced, but *did* not, during the ruinous contest which they themselves set on foot. Wooden pipes, persisted in after iron ones had been invented; stone pipes, rashly adopted on insufficient trial, and burst by the first influx of the water; iron pipes screwed together in inconceivable defiance of the first principles of physics, so that they formed a solid rod, which, by its own contraction in the cold weather, tore itself asunder into fragments about 100 yards long—fragments which had to be patched together, and in that bungled condition remain to this day, a hidden monument of engineering incapacity; all these, and scores of equally costly errors, stand charged against the public as "capital embarked." In what other trade is such a mode of computation admitted? But if, adopting a truer standard, we compare their charges with the real value of the service rendered, as shown by the payment for which it can be, and is, profitably performed elsewhere, we shall find their rates something like 2,000 per cent. beyond the fair market price of the accommodation. Thus, at Tavistock, 4,000 inhabitants, residing in 650 houses, receive a constant and unlimited supply of water at an average charge of 2*s.* 5*d.* per house per annum; the average charge of the West Middlesex being 52*s.* 10*d.* per house per annum, the difference 2,200 per cent. And if 200 per cent. be thrown off to meet the objection that Tavistock is in respect of water service more favourably situated than London, and other such like pleas, there will still remain the monstrous excess of 2,000 per cent. as the measure of monopolist extortion!

No wonder that the public indignation remained unabated; that new water schemes abounded; and that Sir F. Burdett, who had already taken a prominent part in the *free-water* agitation, should again, in 1840, bring this question before a parliamentary committee—this time, however, of the House of Lords.

The Water-Committee of the Lords, in 1840, was specially charged to examine the project of a Mr. Paten, who enjoyed the patronage of Sir F. Burdett, and who proposed to bring water for the supply of London from the springs in a valley at the foot of the chalk hills near Bushey, by an aqueduct 12½ miles long, to a reservoir behind the Eyre Arms at St. John's-wood. This scheme virtually raised the important question how far the Artesian or deep-well system is available as a means of supplying the metropolis with water! Their lordships, however, separated without settling this or any other question, and without even making any report. But they printed the evidence taken before them in an entertaining blue book.

But the water companies, since their confederation in 1818, and after weathering the storms of 1828 and 1834, began to feel and exercise the independent powers of an *imperium in imperio*. In reply to the request of the Lords for returns of their pumping-costs, coal-consumption and the like, they one and all sent civilly-worded but firm and positive *refusals* of the required information.

Having thus, for the third time, passed through the ordeal of a parliamentary investigation without any legislative curtailment of their privileges, the water companies, in 1840, began again to regard their position as impregnable; and from that time to the present day they have accordingly continued to draw from the metropolitan public revenues, constantly augmenting with the annual extension of the town.

In the meantime, however, a new influence, unobserved by them, had been slowly growing up, and silently gathering strength—an influence, which bids fair, at no distant period, to overthrow their confederated strength, and to emancipate London from their henceforth intolerable monopoly. This influence was the Sanitary movement.

In 1842, Mr. Chadwick condensed the information obtained as to the general health and condition of the people, in a report (the first on the Health of Towns) which created a profound sensation, and may be said to have given its first definite shape and powerful impulse to the rising sanitary party. Several thousand copies of this work were eagerly bought, besides 9,000 or 10,000 which were distributed to members of parliament and to the union officers. The horrible consequences of high-priced, scanty, and polluted water-supplies, detailed and *demonstrated* in this book, made a powerful impression on the public mind; and struck a deep though noiseless blow at the root of the metropolitan monopoly.

In 1843 this successful stroke was followed by another from the same hand, in the shape of a supplemental report on Intramural Sepulture—a work which extended and enforced the views of Mr. Walker on this subject; and which, amongst other things, proved the horrible pollution of the urban landsprings by the percolation of graveyard sanies.

These disclosures, though apparently tending to strengthen the water traders by discouraging reliance on the pump as a means of escaping their exorbitant charges, produced, in fact, a precisely opposite effect,—increasing the public abhorrence of the water monopoly by making its absolute and oppressive nature more undeniable.

In 1844 Sir Robert Peel (who had taken office three years previously), perceiving the strong current of public opinion that had set in towards sanitary reform, and fully recognising its importance himself, appointed a commission to inquire into the means and appliances, mechanical and administrative, proper for carrying into effect the sanitary principles that

had been enunciated, especially in respect to the drainage, paving, cleansing, and water supply of towns.

In 1845 the Health of Towns Commissioners produced their report and minutes of evidence on these questions—certainly one of the ablest and most comprehensive state papers that has ever issued from a government office.

Two years afterwards—in 1847—the government of Lord John Russell (who had in the meantime succeeded to office) appointed a commission to report on the means of carrying these principles into effect in the metropolis. This, the Metropolitan Sanitary Commission, which is still open, produced in the same year another admirable report.

In the following year—1848—the gloomy tidings reached us that the Asiatic cholera was rapidly travelling westward, and might be expected shortly to reach our shores. To meet this emergency, the sanitary party, ably represented on this occasion by Lord Morpeth (now Lord Carlisle), introduced and carried through, in spite of strong opposition from interested parties, the Public Health Act.

The prominent tendency of the new health act is to bring about, in every town of the kingdom, an economical *consolidation*, under one responsible public management, of those various services—drainage, paving, water supply, &c., on whose harmonious co-adaptation, hitherto unattainable, the sanitary well-being of the urban population depends.

The water companies, indeed, found means to procure the insertion of a special clause to protect their monopoly from the adverse operation of this act, by threatening its promoters, in the event of refusal, with a degree of opposition and delay, which, with a plague impending, it was in the highest degree important to avoid. The excepting clause, however, stands in such palpable contradiction to the general tenor of the act, that common sense cries out against its maintenance; and the discreditable tactics that procured its insertion, will, we have no doubt, by a just reaction, tend to hasten its inevitable repeal.

Scarcely had the sanitary idea thus acquired force of law, when the fierce outburst of pestilence through which we have just passed gave terrible proof of its necessity. At the eleventh hour, and after a stubborn resistance on the part of several local boards, the house-to-house inspection took place, and led to those dreadful disclosures which are still fresh in the public memory. Day after day men read with indignation and dismay of poor plague-stricken wretches crowded by scores round dribbling standcocks, and literally "*fighting for water.*" Instances still more horrible were reported by hundreds of squalid lanes and courts from which the monopolists *had entirely withheld supplies of water*; passing them by to lay their triple and quadruple rows of competing pipes in richer neighbourhoods promising more lucrative returns. The inspectors' reports, indeed, teemed with the complaints of destitute wretches, thus driven by joint-stock avarice to pump up and drink the waters of drain-infected wells;—of others, if possible, worse off, who had not even a pump to resort to, but begged their daily jugful from door to door;—and of a third set, most miserable of all, whom this last shift of penury had failed, so to use the official declaration of the city medical officer, they "actually lacked water for the ordinary purposes of ablution!"

LIST OF NEW PATENTS.

GRANTED IN ENGLAND FROM NOVEMBER 22, TO DECEMBER 21, 1849.

Six Months allowed for Enrolment, unless otherwise expressed.

William Gossett Taylor, of Binton-house Hall, Westmoreland, gentleman, for improvements in hat, and in felting machines.—Sealed November 24, 1849.

George Callaway, of Putney, Surrey, station agent, and Robert Alex Pinkus, of the same place, engineer, for certain improvements in propelling ships and other vessels; also in apparatus for ploughing land.—November 24.

Charles Cowper, of Southampton-buildings, Chancery-lane, for certain improvements in piling, fagoting, and forging iron for plates, bars, shafts, axles, tyres, cannons, anchors, and other similar purposes.—November 24.

Joseph Barrans, of St. Paul's, Deptford, Kent, engineer, for improvements in axles and axle boxes of locomotive engines and other railway carriages.—November 24.

Ambroise Ador, of Paris, France, engineer, for improvements in producing light.—November 24.

Henry Lamplough, of Snow-hill, London, consulting chemist, for a new mode of supplying pure water to cities and towns.—November 24.

James George Henry and James Newman, of Birmingham, for improvements in the manufacture of buttons, studs, and other dress fastenings and ornaments.—November 28.

Francis Tongue Rufford, of Prescot House, Worcester, fire-brick manufacturer, Isaac Marson, of Cradley, Worcester, and John Finch, of Pickard-street, City-road, Middlesex, manufacturer, for improvements in the manufacture of baths and wash-tubs, or wash vessels.—November 28.

Frank Clarke Hills, of Deptford, Kent, manufacturing chemist, for an improved mode of compressing peat for making fuel or gas; and of manufacturing gas; and of obtaining certain substances applicable to purifying the same.—November 28.

Charles Burlow, of Chancery-lane, London, gentleman, for improvements in the manufacture of a certain pigment. (A communication.)—November 29.

Louis Napoleon Le Gras, of Paris, France, civil engineer, for improvements in the separation and disinfection of faecal matters, in the manufacture of manure, and in the apparatus employed therein.—November 30.

Walter Crum, of Thornliebank, Renfrew, Scotland, for certain improvements in the finishing of woven fabrics.—December 3.

Conrad Montgomery, of the Army and Navy Club, St. James's-square, Middlesex, esq. for improvements in brewing, distilling, and rectifying.—December 3.

William Eccles, the elder, William Eccles, the younger, and Henry Eccles, of Blackburn, Lancaster, cotton spinners, for certain improvements in machinery or apparatus for preparing, spinning and weaving cotton and other fibrous substances.—December 3.

Joseph Paradis, of Lyons, France, merchant for improvements in the manufacture of elastic mattresses, cushions and paddings, parts of which improvements are applicable to other purposes, where sudden or continuous pressure is required to be sustained or transmitted. (A communication.)—December 5.

George Buchanan, of Edinburgh, civil engineer, for improvements in cocks, valves, or stoppers; and in the use of flexible substances for regulating or stopping the passage of fluids; and also in making joints of tubes and pipes, or other vessels.—December 5.

Baron James Ulric Vaucher de Strubing, of Margaret-street, Cavendish-square, Middlesex, for improvements in the manufacture of axletree boxes for carriages, and of the bearings of the axles of railways; and in the making of an alloy of metal suitable for such and like purposes.—December 5.

George Edmund Donisthorpe, of Leeds, Yorkshire, manufacturer, for improvements in wheels of locomotive carriages.—December 5.

Peter Fairbairn, of Leeds, Yorkshire, machinist, and John Hetherington, of Manchester, for certain improvements in machinery for preparing and spinning cotton, flax, and other fibrous substances.—December 5.

Samuel Fisher, of Birmingham, engineer, for improvements in railway carriages, wheels, axles, buffer and draw springs, and hinges for railway carriage and other doors.—December 5.

Edward Carter, of Merton Abbey, Surrey, machinist, for improvements in printing calico and other fabrics.—December 6.

Jonah Davies and George Davies, of the Albion Iron Foundry, Tipton, Staffordshire, engineers and iron founders, for improvements in engines worked by steam, air, water, and other fluids, and whether locomotive, marine, or stationary; and also in boilers, the principle of which improvements is likewise applicable to blowing air and pumping water—December 10.

Jean Baptiste Ecarnot, of France, for improvements in the manufacture of sulphuric, sulphurous, acetic, and oxalic acids, and nitrates.—December 10.

David Christie, of St. John's-place, Broughton, Salford, Lancaster, merchant, for improvements in machinery for preparing, smoothing, straightening, tearing, teasing, doubling, twisting, braiding, and weaving, cotton, wool, and other fibrous substance. (A communication.)—December 10.

John Houghton Christie, of Craven-street, Strand, Esq., for an improved construction of wrought-iron wheels, and machinery for effecting the same. (A communication.)—December 10.

Thomas Grimsley, of Oxford, sculptor, for improvements in the manufacture of bricks and tiles.—December 10.

The Baron Louis Le Presti, of Paris, in France, for improvements in hydraulic presses, which are, in whole or in part, applicable to pumps and other like machines.—December 10.

William Holt, of Preston-place, Bradford, organ builder, for certain improvements in the construction of pallets or valves of organ sound-boards or wind chests, the same being applicable to seraphines, eolophons, harmoniums, harmoniums, and all other musical instruments, in which the tone is produced by the admission of wind, supplied by bellows or other machinery, to pipes, reeds, or springs, and played upon by a key-board, or key-boards, and also to various other purposes connected with all the above-named musical instruments.—December 10.

John Henry Jenkinson, of Salford, Lancaster, machine-maker, and Thomas Priestly, of Shuttleworth, Lancaster, manager, for certain improvements in machinery or apparatus to be used for preparing, spinning, and doubling cotton, wool, flax, silk, and similar fibrous materials.—December 12.

William Hickmore, of Fulbeck Cottage, Hampstead, chemist, for improvements in the manufacture and refining of sugar.—December 12.

Robert Harcourt, of Birmingham, manufacturer, for certain improvements in knobs, handles, and fastenings for doors and drawers; and in fastenings to be used in fastening window sashes, curtain and other rods, and for other like purposes.—December 15.

James Oldknow, of Lille, France, lace-manufacturer, for improvements in the manufacture of lace and other fabrics.—December 15.

Henry Roberts, of Connaught square, Hyde-park, Middlesex, gentleman, for improvements in the manufacture of bricks and tiles.—December 15.

George Wyllies, of Reigate, Surrey, contractor for public works, for improvements in apparatus for receiving and retaining the rails of railways.—December 15.

Alfred Dalton, of West Bromwich, Staffordshire, ironfounder, for improvements in reverberatory and other furnaces.

Charles Cowper, of Southampton-buildings, Chancery-lane, for improvements in instruments for measuring, indicating, and regulating the pressure of air, steam, and other fluids, and in instruments for measuring, indicating, and regulating the temperature of the same, and in instruments for obtaining motive power from the same. (A communication.)—December 15.

Charles Liners, of Paris France, engineer, for improvements in gas meters. (A communication.)—December 15.

Thomas Rock Shute, of Watford, Hertfordshire, silk throwster, for improvements in spinning, doubling, and throwing organzine silk.—December 15.

Timothy Hackworth, and John Wesley Hackworth, of the Soho Works, Shildon, Durham, engineers, for improvements in locomotive and other engines.—December 15.

Benjamin Fawcett, of Old Jewry, in the city of London, builder, for improvements in pigments, paints, and vehicles for painting.—December 15.

Isaac Lewis Pulvermacher, of Vienna, engineer, for improvements in galvanic batteries, in electric telegraphs, and in electro-magnetic and magneto-electric machines.—December 15.

Richard Hobson, of Leeds, doctor of medicine, for certain improvements in the manufacture of horse-shoes, and in apparatus for taking the measurement of horse-shoes or horse's hoofs.—December 18.

Edward Lyon Berthon, of Fareham, Southampton, clerk, Master of Arts, for certain improvements for ascertaining and indicating the course or way, velocity, trim, and draught of ships, and the rate of currents; also for discharging water from ships; and for taking altitudes and levels at sea and on land.—December 19.

James Smith, of Deanston, Perth, now residing in Glasgow, for certain improvements in treating the fleeces of sheep when on the animals.—December 19.

William Ackroyd, of Birkenshaw Mills, near Leeds, Yorkshire, for improvements in dressing and cleaning worsted, and worsted mixed with cotton and other fabrics, after they have been woven. (A communication.)—December 19.

Warren De la Rue, of Bunhill-row, Middlesex, manufacturer, for improvements in the manufacture of envelopes.—December 19.

Frederick Hale Thomson, of Berners-street, Oxford-street, and Edward Varnish, of Kensington, Middlesex, for improvements in the manufacture of ink-stands, mustard-pots, and other vessels of glass.—December 19.

Henry Fox Talbot, of Lacock Abbey, Wiltshire, esquire, and Thomas Augustine Malone, of Regent-street, Middlesex, photographer, for improvements in photography.—December 19.

Joseph Whitworth, of Manchester, engineer, for certain improvements in machinery or apparatus for cutting metals, and also improvements in machinery or apparatus applicable to agricultural or sanitary purposes.—December 19.

Frederick George Spray, and George Worell, of Hampstead-road, engineers, for an improved steam-engine; parts of the arrangements of which may be applied to apparatus for regulating, measuring, and registering the flow of liquids and gases.—December 21.

LECTURES ON ARCHITECTURE,

By SAMUEL CLEGG, JUN., ESQ.

Lecture II.—PHŒNICIA.—ASSYRIA.—PERSIA.—INDIA.

(*With an Engraving, Plate* III.)

In the Egyptian bas-reliefs we constantly meet with battle-pieces, where the enemy against whom the Egyptians are fighting are represented as on an equality with themselves, as regards civilisation and the art of war. These are the Hycsos, the inhabitants of Ludin, names of frequent occurrence on the Egyptian monuments; the former translated by Signor Rosellini as "strangers and wanderers," and the latter denoting the west and south of Asia. We have seen that these Hycsos were sufficiently powerful to overcome the Egyptians, and to keep possession of their country for upwards of a century. The principal nations included in Ludin must have been Phœnicia and Assyria; the former of which touched upon the Egyptian frontier at Pelusium.

We are told that the Phœnicians were an industrious people; the invention of letters is by some writers ascribed to them; and in commerce and navigation they far excelled the Egyptians, who, like the Indians, had a superstitious awe of the sea, and all who ventured thereon.

The Phœnician manufacturers were so celebrated in ancient times, that to whatever was elegant and tasteful in wearing apparel or domestic utensil, the epithet Sidonian was always applied. The most ancient author amongst the Gentiles, of whose writings any fragments have been handed down to us, was a Phœnician, by name Sanchoniatho. He claims for his native country the high honour of having given birth to our first parents; and, like all the old historians who were not particular in separating tradition from fact, evidently places implicit faith in the circumstances he relates. After enumerating several generations, Sanchoniatho says: "Then Hypsuranius inhabited Tyre; and he invented the making of huts of reeds and rushes, and of the papyrus." Then follow three more generations, after which he continues: "Of these were begotten two brothers, who discovered iron and the forging thereof. One of these, called Chrysor, who is the same with Hephæstus, exercised himself in words, and charms, and divinations; and he invented the hook, bait, and fishing line, and boats slightly built; and he was the first of all men that sailed; wherefore he was worshipped after his death as a god, and called Diamichius.* And it is said his brother invented the way of making walls of brick......Afterwards, from this generation were born two youths, one of whom was called Technites, the other Geïnus Autochthôn. These discovered the method of mingling stubble with the loam of bricks, and of drying them in the sun; and found out tiling." In the next generation, we are told, courts and fences for houses were invented, and caves or cellars. Then follow many other generations, and in their course the origin of almost all the useful arts is referred to the Phœnicians.

From the scanty information we possess relative to the architecture of the Phœnicians, we might be led to conclude that this bustling, trading, manufacturing people had not paid as much attention to the arts of architecture and sculpture as their more serious and learned neighbours, the Egyptians. But we are told in one place that the Tyrians were "the first to have advanced the science of architecture to any degree of perfection with regard to proportion, design, and variety of ornament;" and again, that among the Phœnicians not only the Doric order was known, but also a kind of rude Ionic, though with a different entablature. Is it not probable that in the grotto of Beni-Hassan (see engraving in Lecture I., *Egypt*, p. 6), we have a specimen of Phœnician architecture? These polygonal columns differ so widely from the native Egyptian (those in the form of a bundle of reeds), and though the form is again repeated in a second grotto at Beni-Hassan, and at Kalapsche, there is no reason why they may not have been equally imitations. The columns of the principal grotto at Beni-Hassan are pure, primitive Doric, and the dentel on the architrave has been found (as far as I have been able to ascertain) nowhere else in Egypt. We have no means of knowing in what style the more ancient buildings of This and Memphis may have been constructed; but as the sacred architecture was under the control of the priests, and as the most ancient was always held in the highest veneration, we have no reason to suppose that it differed from that of Karnac and Luxor, where no vestige of Doric appears, though the former temple was commenced about the same time as the grotto of Beni-Hassan (1600 B.C.) We learn from the inscription that Nahride Nevothph was a general—is it not probable that in some incursion into Phœnicia, he had seen and been struck with the Doric architecture, and had imitated it in his tomb? which, no doubt, for so eminent a man, had been prepared during his lifetime. It is strange that of a country so flourishing, and from which such numerous colonies were sent out, we should have no more exact information: even of its greatest daughter, Carthage, once the proud rival of Rome, there is now scarcely one stone left upon another, to tell what has been.

In the sacred writings we have an account of Hiram, king of Tyre, exchanging gifts with King Solomon: it seems they were both great builders. We find these monarchs mentioned, also, in a fragment of 'Dius' (Tyrian annals); but there, instead of being instructed in the style of King Hiram's building, we find these great potentates amusing themselves with setting each other riddles, and playing at forfeits. The anecdote runs thus: "Upon the death of Abibalus, his son, Hiromus (or Hiram), succeeded to the kingdom. He raised the eastern parts of the city, and enlarged it; and joined to it the temple of Jupiter Olympius, which stood before on an island, by filling up the intermediate space; and he adorned that temple with donations of gold. And he went up into Libanus (Lebanon), to cut timber for the construction of the temples......And it is said that Solomon, king of Jerusalem, sent enigmas to Hiromus, and desired others in return, with a proposal that whichsoever of the two was unable to solve them, should forfeit money to the other. Hiromus agreed to the proposal, but was unable to solve the enigmas, and paid a large sum as forfeit......And it is said that one Abdemonus, a Tyrian, solved the enigmas, and proposed others which Solomon was not able to unriddle, for which he repaid the fine to Hiromus." It is worthy of remark, that mention is here made of a temple of Jupiter Olympius, in Tyre, about 1012 B.C.; the first authentic record of any temple erected in Greece being some centuries later. The inhabitants of Ægina, indeed, claim Æacus, son of Jupiter, as the founder of their temple of Jupiter Panhellenius; but it is needless to observe that such legends are worthy of little credit.

We now proceed eastward to Assyria, whose sovereigns styled themselves "king of kings," as an assertion of their power and greatness. Until the present day, the Assyrians were even more enveloped in mystery than the Phœnicians; but by the talents and energies of Mr. Layard much has been revealed to us. All honour to him, and such as he is! There is a child's story, where a magician, by waving a wand before a mirror, brings over its magic surface the images of people and things belonging to long past ages,—nor is the story altogether a fable: it is our historians and antiquarians who are the true necromancers, bringing to our view scenes, and even the likenesses of those whose very existence had passed into the twilight of legendary times. We need not leave London to see Nimrod, "the mighty hunter," face to face; and to make ourselves as familiar with the eunuchs and ministers of the Assyrian court, as Holbein has made us with Henry VIII. and Cardinal Wolsey.

According to an ancient tradition, a civilised people possessed the country when Ninus founded the Assyrian empire; and having conquered this people, he attempted to destroy their works. We have no certain date of the reign of Ninus, but there is no reason to suppose the Assyrian empire less ancient than the Egyptian. Berossus, the Chaldean historian, a priest of Belus, who wrote in the time of Alexander the Great, describes Babylonia as a country which lay between the Tigris and Euphrates: "It abounded with wheat and barley......There were also palm trees, and apples and most kinds of fruits; fish, too, and birds......At Babylon there was (in these times) a great resort of people of various nations, who inhabited Chaldea, and lived without rule and order, like the beasts of the fields." He then goes on to describe how an animal, part man and part fish, came up from the Erythræum sea, which bordered upon Babylonia, and "taught them to construct houses, to found temples, to compile laws, and explained to them the principles of geometrical knowledge; he made them distinguish the seeds of the earth, and showed them how to collect fruits: in short, he instructed them in everything which could tend to soften manners, and humanise mankind."

The ruins of Babylon and Nineveh now present to the eye of the traveller, only vast mounds of earth; nor were there many more striking remains of the latter great city when Xenophon passed by with his "ten thousand," twenty-two centuries ago. To quote from Mr. Layard: "The graceful column, rising above the thick foliage of the myrtle, ilex, and oleander; the gradines of the amphitheatre, covering a gentle slope, and overlooking the dark blue waters of a

* The name "Hephæstus" occurs in the list Manetho gives of kings in Egypt.

lake-like bay; the richly-carved cornice or capital, half hidden by the luxuriant herbage; are replaced by the stern, shapeless mound, rising like a hill from the scorched plain,—the fragments of pottery, and the stupendous mass of brickwork, occasionally laid bare by the winter rains......The scene around is worthy of the ruin he is contemplating; desolation meets desolation,—a feeling of awe succeeds to wonder; for there is nothing to relieve the mind, to lead to hope, or to tell of what has gone by." This description brings forcibly to mind the words of prophecy: "And he will stretch out his hand against the north, and destroy Assyria; and will make Nineveh a desolation, and dry like a wilderness. And flocks shall lie down in the midst of her, all the beasts of the nations; both the cormorant and the bittern shall lodge in the upper lintels of it; their voice shall sing in the windows; desolation shall be in the thresholds: for he shall uncover the cedar work. This is the rejoicing city that dwelt carelessly, that said in her heart, I am, and there is none beside me: how is she become a desolation, a place for beasts to lie down in!"

The architecture of the Assyrians offers a striking contrast to that of the Egyptians; nor, in taking the soil and situation into consideration, are we at a loss to account for the difference.

Nineveh, Babylon, Risen, and other great cities, had no doubt been founded on the banks of the Euphrates and Tigris for the sake of the easy transit afforded by the rivers, as well as for the great fertility caused by the abundant supply of water. Assyria occupied a vast plain, bounded on the north and east by the mountains of Armenia and Khurdistan; and on the west by the Arabian desert. Stone, of a serviceable kind, could only be brought from the distant mountains by an immense expenditure of time and labour, and was consequently only employed on statues, obelisks, &c.; and wood appears also to have been scarce, for Berossus, when enumerating palm, apple, and different kinds of fruit, makes no mention of timber trees; nor have the present inhabitants of the country any other than the palm and the poplar. Cedar was doubtless imported from Phœnicia, but must have been too valuable to use as a common building material. The Assyrians were, therefore, wholly confined to the use of brick, and the native coarse alabaster, which could only be used for cutting into slabs: this want of stone accounts for the total absence of fragments of columns, generally so abundant amongst ancient ruins. Strabo tells us they constructed columns of palm trees, round which, by way of ornament, they twisted bulrushes painted in various colours. These are probably the kind of columns represented on their sculptures; but of such frail materials all vestiges would naturally soon pass away.

The walls of Babylon have been a fertile source of exaggeration; but allowing for this, they must have been extraordinary works, and to the dwellers in the open plain they formed the only means of defence. According to Diodorus Siculus, there was sufficient space within the outer walls of Babylon not only for gardens and orchards, but to cultivate corn enough for the subsistence of the whole population, in case of siege: each city had also a citadel, and a ditch round the walls. The citadel was the holy place, where the palace-temple stood, where the treasures were kept, and where were preserved the records of the kingdom, carved in stone; it was also the place of refuge in time of danger. This sacred ground was elevated above the other buildings, both to give dignity to the palace-temple and strength to the citadel. In these plains, where no natural eminence was at hand, a regular platform of crude brick was constructed, 30 or 40 feet in height: the custom of building on elevated ground still exists, and many of the ancient mounds are occupied by a modern citadel. It was to defend this sacred inclosure that those huge walls were built, so often celebrated by ancient authors. Herodotus speaks of the walls of Babylon as 300 feet in height, and about 75 feet in thickness; and, according to Diodorus, the walls of Nineveh were 100 feet in height, and so broad that three chariots might be driven abreast upon them; 1500 towers were built at intervals along the walls, each 200 feet in height. Whether these dimensions be correct or not, it is certain that the fortification must have been of prodigious strength, as, in the reign of Sardanapalus, Nineveh was only subdued by the combined forces of the Persians and Babylonians, after a siege of nearly three years. At certain distances in the wall were the gates, either flanked by towers, or ornamented at the entrance by gigantic figures, such as the winged bull. The exterior of the wall was frequently cased with square slabs, most probably of the native alabaster, and was decorated with paintings. Ezekiel speaks of these paintings: "For when she saw men pourtrayed upon the walls, the images of the Chaldeans pourtrayed with vermilion; girded with girdles upon their loins, exceeding in dyed attire upon their heads." Diodorus says that on the outside of the principal palace of Babylon, built by Queen Semiramis, figures of men and animals were painted; and that the paint was laid on the bricks before they were placed in the furnace. Some enamelled bricks have been found at Nimroud, on which the colours appear to have been thickly laid in a liquid state, and afterwards baked in.

Of the architecture of the palaces of Babylon we have no account; but we may suppose it to have resembled the style of those structures discovered by Mr. Layard. Strabo has left us an account of the temple of Belus; by whose description it would seem to have been a pyramidal tower, of eight stories, with a winding staircase on the outside from the base to the summit, the highest story containing an observatory, fitted up for astronomical purposes. We are told also of quays, of beautiful workmanship, along the banks of the river; and of a bridge built by Semiramis over the narrowest part of the Euphrates, "founded with wonderful skill" in the bed of the river, supported by columns 12 feet apart. In order that the stones of which the bridge was composed should be firmly united, they were bound together by cramps of iron, run with lead; and to break the force of the water against the columns, sloping masses of masonry were built up against them; the roadway of the bridge was formed with beams of cedar and cypress, and was 30 feet in breadth. Dams were also constructed across the river, to secure a constant supply of water to the numerous canals, which spread over the country like network, and were known to have been the work of an ancient people in the time of Alexander the Great.

I fear the preceding descriptions must be taken as somewhat apocryphal, when we consider for how many centuries the mighty cities of Assyria have lain a heap of ruins; according to Mr. Layard, however, the Arabs state that when the river runs low, huge stones, united by cramps of iron, become visible, which they assert to have been the work of Nimroud.

It is not probable that any judgment can now be formed of the exterior architecture of Nineveh, so completely are the buildings buried in heaps of earth and rubbish; and it was only by laborious excavations that Mr. Layard gained an entrance into the interior of one of the great palaces. It is most probable they were flat-roofed, and did not rise above the height of one story. The walls of the chambers were constructed of sun-dried bricks, and were from 5 feet to 15 feet in thickness; from 9 feet to 12 feet of the height of this wall was panelled with slabs of the coarse alabaster or gypsum, with which the plains of Mesopotamia abound. The slabs were fixed in their place by wooden or metal cramps, dovetailed into corresponding grooves in the adjoining slabs. After the wall was formed, the bas-reliefs and inscriptions were chiselled out: this is evident from the manner in which the sculptures and ornaments are continued from one slab to another. The wall above this alabaster panelling was formed either of richly-coloured baked bricks, or of sun-dried bricks covered with a coat of plaster, and variously decorated and painted. Here, several ornaments, now familiar to us through Greek art, appear to have originated—amongst others, the guilloche, and the device known as the Greek honeysuckle, or palmette. Assyrian art influenced that of Asia Minor, and so was transmitted to the Greeks, who knew so well how to harmonise and beautify every idea they borrowed, that what they produced from the crude conceptions of other nations was like the perfectly developed flower compared with the just opening bud. The roof in Assyrian buildings was formed of beams of wood; small beams, planks, or branches of palm were laid across them, and the whole plastered over on the outside. The disproportionate narrowness of the chambers would seem to forbid the idea of interior support by means of columns; one hall of the palace, though 160 feet in length, is only 35 feet in breadth. In the wider halls, it is probable that the centre was open to the air; indeed, it is to be presumed that all the chambers were lighted through an opening in the roof, unless artificially illuminated, for there are no traces of windows; and drains are found leading from each chamber, as if for the purpose of carrying off the rain that might have fallen from above. In the open halls it is conjectured that a projecting ledge may have been carried round the walls, sufficiently wide to afford shade and shelter,—and here, probably, the palm columns mentioned by Strabo were employed as supporters. The ceilings or soffits were divided into square compartments, decorated with painted flowers, or figures of animals, and surrounded by elegant borders and mouldings: in some instances, the compartments were inlaid with ivory, and the beams gilded.

The pavements were formed either of inscribed alabaster slabs, or baked bricks; at the threshold of each chamber, beneath the

pavement, a small image was deposited, intended as a protection to the household. The entrance was guarded on either side by human-headed bulls, or sphinxes; the former were from 10 feet to 16 feet in height. The Assyrian sphinx was winged—thus adding the idea of ubiquity to that of physical and intellectual power; they occupied the same position here as in Egypt, and were in a like manner a type of the governing power.

Assyrian Sphinx.

The colours used by the Assyrians were the same as those employed in Egypt—copperas blue, red and yellow ochres, lampblack, and calcined gypsum. There is no doubt that they were skilful workmen, and well acquainted with the use of metals. Of their skill in carving stone, we have only to examine the human head of the bull, and the small black obelisk, now in the British Museum, fully to satisfy ourselves.

I shall close this account of Assyria with another extract from Berossus, relating to Nebuchodonasor. He says: "Nebuchodonasor ordered the captives [Jews, Syrians, and Egyptians] to be distributed in colonies in the most proper places of Babylonia; and adorned the temple of Belus, and the other temples, in a sumptuous and pious manner, out of the spoils he had taken in this war. He also rebuilt the old city, and added another to it on the outside; and so far restored Babylon, that none who should besiege it afterwards might have it in their power to divert the river, so as to facilitate an entrance into it: and this he did by building three walls about the inner city, and three about the outer. Some of these walls he built of burnt brick and bitumen, and some of brick only......When he had thus admirably fortified the city with walls, and had magnificently adorned the gates, he added also a new palace to those in which his forefathers had dwelt; adjoining them, but exceeding them in height and in its great splendour. It would, perhaps, require too long a narration, if any one were to describe it: however, as prodigiously large and magnificent as it was, it was finished in fifteen days. In this palace he erected very high walls, supported by stone pillars; and by planting what was called a pensile paradise, and replenishing it with all sorts of trees, he rendered the prospect an exact resemblance of a mountainous country. This he did to please his queen, because she had been brought up in Medea, and was fond of a mountainous situation." This account places Nebuchodonasor before us in an amiable and poetical light, building up mimic mountains for his young Medean bride, to woo her into forgetfulness of her exile: for we can imagine her pining in the wide plains of Babylonia, being, as Berossus says, "fond of a mountainous situation."

Nineveh was destroyed by the united arms of Cyaxares, king of Persia, and Nabopolassar, king of Babylon, 606 B.C.; and Babylon shared the same fate in the following century, 538 B.C.

The ancient Persians do not appear to have been so learned or cultivated a people as the Egyptians and Assyrians, and evidently borrowed much of their architecture from their more civilised adversaries. When Cambyses conquered Egypt (524 B.C.), he not only carried away rich spoils and many works of art, but also skilful artificers; and it is evident that Cyaxares and Cyrus were not more scrupulous with regard to the Assyrians. We may form some idea of the appropriating propensities of the Persians, when we read that Ptolemy Euergetes, when he invaded the Persian dominions, brought back 2500 statues and other Egyptian works of art. According to the most ancient native authorities, Persia dates as a kingdom from a very remote period, and was governed by a race of kings called the Paishdadian, or distributors of justice; the most celebrated amongst these was the renowned Jemsheed, as familiar a name in ancient Persian history as that of Shah Abbas in more modern times. Persepolis is said to have been founded by this race of kings, and hence its native name is Tackt-i-Jemsheed, or the throne of Jemsheed. The only other ancient Persian cities of which any tradition or ruins exist, are Echatana (the ancient capital of Medea), Susa, and Pasargadæ, the royal city of Cyrus.

We have the same extravagant accounts of the walls of Persian as of the Assyrian cities. According to Herodotus, Echatana was surrounded by seven walls, each one rising above the other towards the citadel, and each painted a different colour; and the walls of Susa are described as above 120 stadia (15 miles) in circumference. After the kingdoms of Persia and Medea were united under Cyrus (550 B.C.), Echatana was the summer, and Susa the winter residence of the monarch, on account of the warmer climate of the latter city. The royal treasures were kept at Susa, and the palace is described as having been built of white marble, and its pillars covered with gold and precious stones; indeed, the Persians, though at first hardy and simple in their habits, appear soon after their union with the more luxurious Medes, to have imbibed that taste for gorgeous colouring, and elaborate ornament, that distinguishes the Persian architecture at the present day.

The remains of Persepolis, Echatana, and Pasargadæ, are sufficient to show that the same style of architecture prevailed throughout the Persian kingdom, and how nearly it resembles, in some respects, Egyptian architecture, and in others that of Assyria. Quintus Curtius speaks of Persepolis as "the glory of the East," and says that no other city existed that could be compared with it. Diodorus Siculus says, "A triple wall encircled the palace. ......The first wall was 16 coudes in height, defended by parapets, and flanked with towers; the second wall was in form like the first, but twice its elevation......The third wall was a square, and cut in the mountain, being 60 coudes in height. It was defended by palisadoes of copper, and had doors of the same, of 20 coudes high...... The first wall was to inspire awe, the second for strength, and the last for the defence of the palace." The principal ruin now remaining of Persepolis is called the Palace of Forty Pillars: the first object that attracts the eye is a large and high square platform, which is divided into three parts, each raised above the other. The stones of which this platform is constructed are of enormous size, some as much as 52 feet in length; and most of them from 30 to 40 feet in length, and from 4 feet to 6 feet in height; they are carefully hewn, and most of them polished; and so admirably fitted, that even after this lapse of time the joinings are almost imperceptible. The communication from one part of the platform to another is by means of a staircase, so wide that ten horses might ascend it abreast. The columns and fragments around would appear to have formed a vast portico; four pilasters remain, each 4 feet in thickness, and from 24 feet to 25 feet in height, probably forming the entrance, as on these are carved the human-headed bull, precisely similar to those found at Nineveh. Sir John Chardin speaks of thirteen columns as standing when he visited Persepolis, two hundred years ago, but several have since fallen: the columns are of white marble, with fluted shafts of slender proportions. The Persian capitals occupied a great proportion of the height of the column, and were of singular form—some being ornamented with rows of small volutes, something like the curls of an old-fashioned bag-wig, while others were surmounted by busts of the unicorn-bull: the bull being sacred to the worship of Mithra, it may be presumed that the columns with this form of capital were part of some religious structure. There are several niches yet standing, that no doubt formed part of the wall of the building: such niches are frequently seen in Persia at the present day, and are occupied by vases of flowers or plants. What makes these niches at Persepolis worthy of remark is, that they are finished with the bead-and-cavetto moulding, precisely similar to the doorways in Egypt. Another interesting part of the ruin is a terrace, on which are carved two ranges of bas-reliefs, representing a procession; the figures are a little less than 4 feet in height, and bear a remarkable resemblance to the Assyrian sculptures.—Perse-

polis was destroyed by Alexander the Great, after the defeat of Darius (331 B.C.)

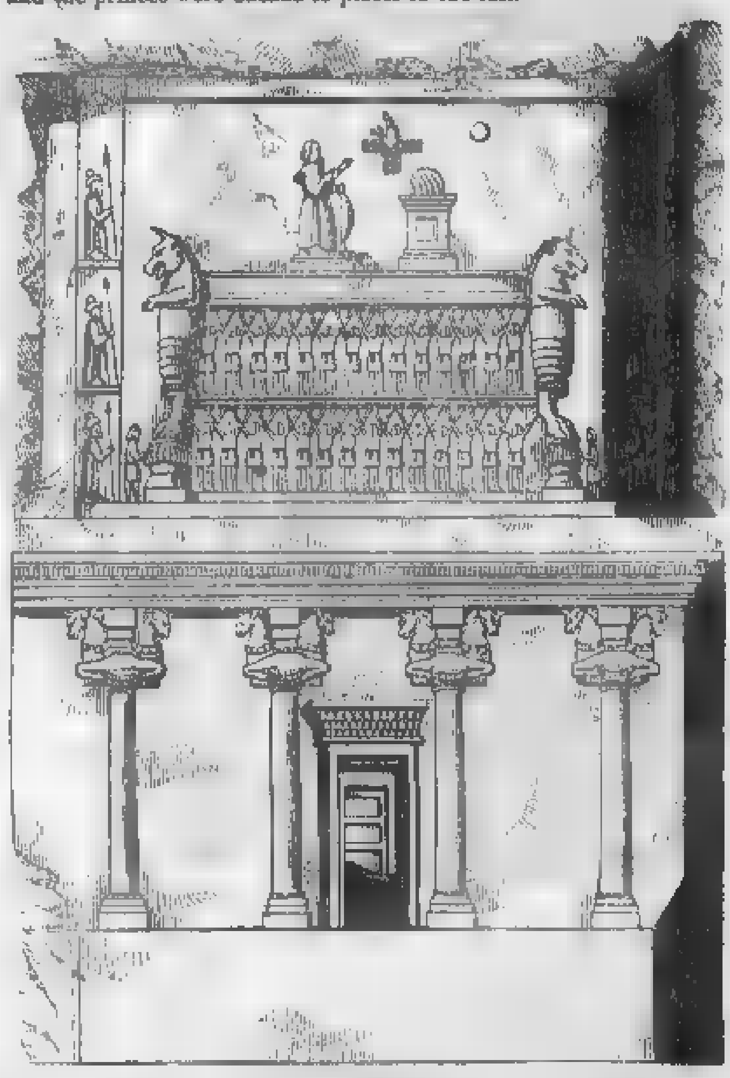
It would appear singular, at the first glance, that while Egypt and India abound in ruins of sacred buildings, a great and wealthy nation like Persia should possess so few: to account for this peculiarity, we must take into consideration the ancient faith of the people. Both Herodotus and Strabo assert that the Persians had neither temples, images, nor altars, but that they offered up their sacrifices on mountains or high places: this must be understood to allude to a very remote period, when the Persians were still worshippers of Mithra, the sun, as the type of the one supreme Deity. This simple form of faith continued until the time of Zerdusht, or Zoroaster, who introduced fire-worship. After his time, small shrines or tabernacles were built, for the preservation of the sacred flame; and altars were cut out of the rock, on which to offer sacrifice.

Two ancient altars remain near Nakshi Roustam; both standing on the same platform of rock, 12 or 14 feet from the ground; a flight of steps, hewn out of the solid, ascends from the south to the foot of them; each altar is a square of 4 ft. 6 in. gradually tapering to 3 feet; a heavy and rudely-shaped column runs up each corner, and rests on a square plinth; the capital is formed by a kind of torus, and a semicircular arch, in relief, extends from pillar to pillar. In the square top of the altar is a hollow, excavated to the depth of 8 inches, probably for the reception of the sacred fire. A fire tabernacle still exists in the same neighbourhood: this small building is much choked up with earth, but its present height is about 35 feet; it is built of marble, and curiously ornamented with projecting blocks along each course. The chamber is a square of twelve feet, the walls of which are completely blackened with smoke. When temples were first erected in Persia, they were still on high places, and open to the sky, the worship of Mithra forbidding the attempt to confine the Deity under a covered roof as impious.

In the reign of Darius Hystaspes, some alterations in religious forms were made, when the temples were roofed-in, the better to preserve the holy fire from the accidents of the weather; but the old belief in the superior sanctity of the canopy of the heavens never became extinct. The comparatively short period that elapsed between the reign of Darius Hystaspes (485 B.C.), and the annihilation of the Persian kingdom under Alexander the Great (331 B.C.), sufficiently accounts for the scanty remains which are found of these temples.

A few miles from Persepolis [redacted] the Nakshi Roustam, or mountain of sepulchres, showing by its extensive and numerous excavations that the adorers of the sacred fire were no less anxious for the preservation of their mortal remains than the worshippers of Osiris. This mountain is composed of a whitish marble, and rises almost perpendicularly to the height of about 900 feet. In the face of it numerous tombs have been cut, evidently of a date coeval with the prosperous days of the neighbouring city of Persepolis. The earliest and most elaborate sepulchres are the four highest in the rock; they are all similar—a description of one will therefore suffice. The façade of the tomb is divided into three compartments; the upper one is richly sculptured with figures in relief; beneath this is the entrance; four attached columns support an architrave, simply ornamented by dentils near its upper ledge. The bases of the columns consist of a torus and plinth, projecting 1 ft. 6 in. from the face of the tomb. The capitals are composed of the head, breast, and bent fore-legs of two unicorn-bulls, richly adorned with collars and trappings, united just behind the shoulders, leaving a cavity for the insertion of a block of stone to support the connecting architrave. Between the two centre columns is the doorway, having for its cornice the Egyptian bead-and-cavetto moulding; the greater part of the apparent door is only panelled, the entrance being confined to a square space of 4 ft. 6 in. high in the lower part of it. The third and lowest compartment has a smooth surface, terminating below in a deep hollow cut in the rock. The whole front is about 53 feet high. The chamber of the tomb is vaulted, and is 34 feet in length and 9 feet in height, the breadth of it being occupied by three arched recesses at its farthest extremity; each of these contains a trough-like cavity, hollowed out of the rock, 8 ft. 3 in. in length by 5 ft. in breadth, which no doubt contained the sarcophagus or the bodies; and they were covered by a stone of corresponding dimensions. The only mode of reaching these tombs is by means of a rope, the face of the rock affording no footing.

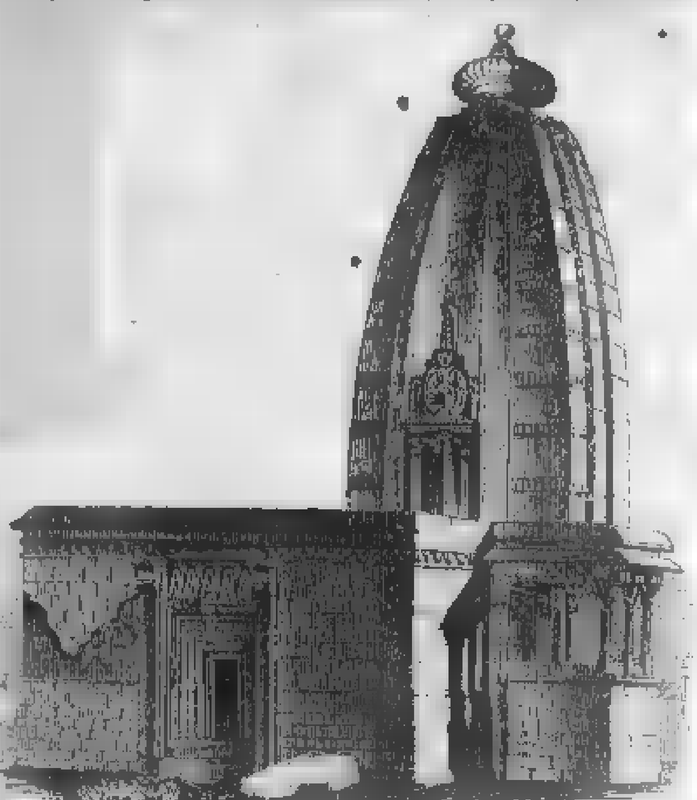
The tomb somewhat lower in the rock, on which is seen an inscription in the cuneiform character, is supposed to be that of Darius Hystaspes. It was on this spot, upwards of two thousand years ago, that the following catastrophe happened, as related by Ctesius:—An elaborately decorated tomb had been prepared by the orders of Darius Hystaspes, that his body might repose in due honour after death; but when intending to inspect it on its completion, he was forbidden to do so by the Chaldean soothsayers, who prophesied that some fearful accident would follow such an attempt. Darius submitted; but some young princes of his family, more courageous or less superstitious, determined, in spite of warnings, to view the interior of the tomb. The officiating priests agreed to draw them up to the entrance; but while they were yet suspended in the air, several serpents suddenly appeared on the rock, and so startled the priests that they at once let go the rope, and the princes were dashed to pieces in the fall.



Nakshi Roustam.

The Mithratic worship, though apparently at some remote era extending over almost all the then known world, lost its simplicity, and gave place to idolatry much sooner in some countries than in others; thus, while in Persia it was retained for many centuries, in Egypt and India it was soon confounded amongst other creeds, though never wholly disappearing: in India, therefore, temples exist from as early a period as in Egypt. It has been a subject of frequent discussion, which country can lay claim to the greatest antiquity, and whether (some resemblance being found in the arts and architecture of the two countries) one was derived from the other, or whether both may be esteemed coeval and original. I incline to the latter opinion. It does not appear that any resemblance exists that may not be accounted for by similarity of climate, and a common Asiatic origin. The palm and lotus are represented in the ornaments of both countries, because the palm and lotus flourish on the banks and in the waters of the Ganges, as well as of the Nile. The same gigantic proportions were aspired to by all the nations of antiquity; and we are equally struck with the magnitude of the ruins at Persepolis and in Central America, as with the temples of Egypt and the pagodas of India.

But if we notice points of resemblance, we must also notice striking marks of dissimilarity—for instance, the Egyptians always made ornament subservient to a meaning, and never allowed it to interfere with the grandeur of the outline: the Hindoos, on the contrary, sacrificed purity of outline to the elaborate ornament with which their pagodas are overloaded. In Egypt, the temples were of one simple angular form; and the peculiar worship to which they were dedicated, whether of Osiris, Amun, or Athor, was taught by the sculptures and hieroglyphics on the walls: in India, the whole *exterior* form of the temple was made to bear a certain significance; thus a corrupted form of Mithratic worship gave the circular dome, which in the interior was to represent the holy concave of the heavens, and was sprinkled with stars on an azure ground, or decorated with a sculptured zodiac; other pagodas took the more ancient pyramidal form, and some the two combined, showing a pyramid terminated by a cupola or globe; other

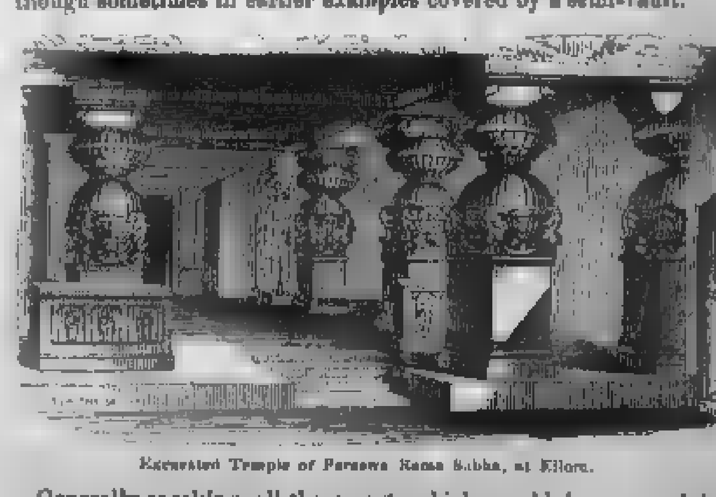


Hindoo Temple at Deo, in Bahar.

Indian temples assumed, from the theology of their builders, the oval form of the mundane egg; and others, again, a square or cross, symbolical of the four elements and four cardinal points. The Egyptians, though avoiding all expression of human action or passion in their statues, never gave them those additional heads and limbs that deform Hindoo sculpture: while in some of the Indian bas-reliefs there is an idea of grouping and graceful attitude, not seen amongst the Egyptians.

The term "pagoda" applied to Indian and Chinese temples is derived from the Persian words *pout*, an idol, and *ghada*, a temple. The exterior of the pagodas are generally covered with figures of Indian deities or animals, sculptured with great spirit; and the lofty walls and ceiling of the interior are profusely adorned with rich painting and gilding: daylight is only admitted by the solitary entrance-door, but they are illuminated by ever-burning lamps suspended from the roof. The banks of the Ganges, Kistna, or other sacred rivers is, when possible, selected for the site of the great temples, in order that the worshippers may have the benefit of ablution in the holy stream: when the pagodas are at a distance from the river, a large quadrangular tank or reservoir is constructed in front, lined with freestone or marble, and having a flight of steps descending from the margin; many of the tanks are from 300 to 400 feet in breadth. The entrance to all the principal pagodas is formed by a portico with lofty columns, and ascended by a flight of stone steps, sometimes, as in that of Tripelli, to the number of one hundred. The gate is always fronting the east. The interior is divided into three parts, which may be compared to a centre and two side aisles; at the further end is the sanctuary, surrounded by a stone balustrade to keep off the populace. The pagoda of Santidus, in Guzzerat, is described by Tavernier as including three courts, paved with marble, and surrounded by porticoes supported by marble columns, and decorated with female figures sculptured in the same material. Into the inner court no one was allowed to enter without taking off his sandals. The ceilings and walls of the interior of the pagoda are adorned with mosaic work and variously coloured agates. The courts of the temple of Seringham, measured round the outer wall, are nearly four miles in circumference, and are entered through immense pyramidal gateways on each of the four sides. The pyramidal gateways leading to the magnificent pagoda of Chillambrun, on the coast of Coromandel, exceed 120 feet in height. The Choultry, or hall, in some cases is of enormous size, having 100 columns in length and 10 in width, or 1,000 columns in all: they are popularly called "halls of a thousand columns;" and this is usually literally true. When it is remembered that each of these columns is ornamentally carved from capital to base, that these carvings are usually all different in design, and that the material used is granite, it must be admitted that they are wonderful works.

The excavated temples of Hindostan have afforded a fertile theme for argument,—some authors taking their remote antiquity for granted, while others deny their existence beyond the invasion of the Saracens. Lieut. Fergusson upholds the latter opinion, principally on account of the frequent use of the arch. Now, the vault being a sacred form, a section of it may have been adopted in ancient times, and thus account for the semicircular arch so constantly found in these rock-cut temples; yet we must allow that when the ogee arch also appears, it affords conclusive evidence of their more recent date, as it is well known that this form was first employed by the followers of Mahomet. The remote antiquity of the excavations in India, as in Egypt, is objected to because most of them are imitations of structural models. Lieut. Fergusson says, that the Brahminical caves are always imitations, though those of the Buddhists are generally simple excavations. A mistake may have arisen from treating these rock-cut temples as if excavated at one period, when it is probable they were the work of successive centuries; for it is known that the Buddhists were the earliest cave-diggers, and that they made use of natural caverns, which they improved by art. The most simple excavations consist of a square cell with a porch; but frequently in the monastery caves, the verandha or porch opens into a square hall, three sides of which are occupied by cells—the hall being sometimes so large as to require the support of pillars; in a deep recess of it, facing the entrance, is placed a statue of Buddha: thus the cave is a place of worship as well as an abode for the priests. The Brahminical caves have generally a temple attached, which consists of an external porch, an internal gallery over the entrance, and a centre aisle twice the length of its breadth, having a vaulted roof, terminating in a semi-dome, under which stands a dagopa; a narrow aisle surrounds the whole interior, separated from the centre by a range of massive columns. This side aisle is generally flat-roofed, though sometimes in earlier examples covered by a semi-vault.



Excavated Temple of Parsowa Rama Sabha, at Ellora.

Generally speaking, all those parts which would be of wood in structural buildings, are of wood in the caves; when this is not the case the same forms are preserved, though carved in the rock. The cave-temples are usually lighted by a large aperture over the entrance, having the striking effect of throwing the full blaze of light upon the idol, while the rest of the cavern remains in com-

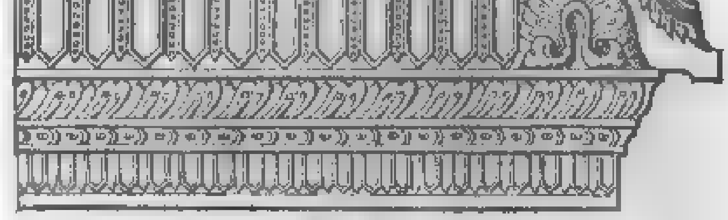
parative gloom. There are numerous groups of excavations throughout India, at Elephanta, Salsette, Ellora, and elsewhere. Lindschotten describes the caves of Salsette as so many separate ranges of apartments, rising in succession to four galleries or stories, containing as many as 300 chambers. The caves of Ellora, near Aurungabad, are amongst the most interesting—and the massive columns, with the cushion capital, the best specimens of this style. Some of the "ruths," or monolithic shrines, are cut out of isolated blocks of granite; others have the rock out of which they were cut so close round them, that they stand as it were in a pit, and are consequently imperfectly seen. Sometimes the excavated caves and monolithic shrines form a group, the latter being generally of a pyramidal form.

Oude is said to have been the first imperial city of Hindostan. Sir Wm. Jones says, "that if we may believe the Brahmins, it extended over a line of about 40 miles, and the present city of Lucknow was only a lodge for one of its gates." According to the 'Mahabharat' (an Indian historical poem), Oude continued to be the chief city, until the erection of Canouge on the Ganges, about 1000 B.C.; at which time idolatry was introduced, idols set up, and Canouge adorned with numerous royal and sacred edifices. The regular empire of India may be said to have fallen with Callian Chund, who reigned over Hindostan about 170 B.C. Palibothra was the ancient city of which Strabo asserts that it was situated at the conflux of another river with the Ganges; that its figure was quadrangular; that in length it was 80 stadia, and 15 in breadth; and that it had a fortification of wood, with turrets for the archers to shoot from; and that it was surrounded by a vast ditch. Delhi was founded about 300 B. C. This city is described by the Persian historian Sherifeddin as consisting of three cities, Seiri, Gehampenah, and old Delhi or Inderput. Seiri and old Delhi were encircled by a wall; Gehampenah occupied the space between the two former, and was considerably larger than either; the walls by which it was fortified ran in parallel lines on each side, and connected Seiri and old Delhi. This threefold city spread over a vast extent of ground; according to Sheriffedin, it had thirty (others say fifty) gates: he informs us also that it was celebrated for a magnificent palace, erected by an ancient king of India, and adorned with one thousand marble columns. This noble city was destroyed by Timur, but rose again under his successors; when Agra was also founded, and strongly fortified.

The most wonderful amongst these monoliths or excavations is Kylas, or Paradise, near Aurungabad; this presents the appearance of an assemblage of temples, shrines, and columns, of various dimensions,—the whole loaded with minute and fanciful ornament that baffles description. The portico of one of the largest of the temples is supported by colossal elephants, and the front is entirely covered with figures of idols, animals, and arabesques, in infinite variety. For an idea of this marvellous excavation, I must refer the student to the beautiful and elaborate drawing of Lieut. Fergusson, in his work entitled, 'Illustrations of the Rock-cut Temples of India.'

The rules and principles of architecture, like those of most other sciences in India, have been locked up in the Sanscrit language; and every attempt made by the workmen to diffuse the knowledge they verbally received, was considered an encroachment upon the rights and privileges of the higher orders. Some interesting translations have, however, been given by Ram Raz, himself a Hindoo. The Sanscrit writings commence with various aphorisms, such as: "An architect should be conversant in all sciences; ever attentive to his avocations; of an unblemished character; generous, sincere, and devoid of enmity or jealousy......Woe to them who dwell in a house not built according to the proportions of symmetry. In building an edifice, therefore, let all its parts, from the basement to the roof, be duly considered." Then follow rules for choosing the ground: "The best sort of ground," says the Sanscrit author, "should abound with milky trees, full of fruits and flowers; its boundary should be of a quadrangular form, level and smooth, with a sloping declivity towards the east; producing a hard sound; with a stream running from left to right; of an agreeable odour; fertile; of an uniform colour; containing a great quantity of soil; producing water when dug to the height of a man's arm raised above his head; and situated in a climate of moderate temperature." The ground to be avoided is, "That which has the form of a circle; a semicircle; containing three, five, or six angles; resembling a trident, or a winnow; shaped like the hinder part of a fish, or the back of an elephant; or a turtle, or the face of a cow, and the like. Abounding with human skulls, stones, worms, ant-hills, bones, slimy earth, decayed woods, dilapidated walls, subterraneous pits, fragments of tiles, limestones, ashes, husks of corn; or exposed to the wafted effluvia of curds, oil, honey, dead bodies, fishes, &c. Such a spot should be avoided on every account." Then follow rules for ascertaining the solidity of the ground, and for various ceremonies, which so nearly resemble those practised at the founding of Rome, and consequently Etruscan, that they need not be mentioned here. The whole area of a town or village (according to the ancient authority), with the lands thereunto belonging, being divided into twenty equal parts: one is assigned for the occupation of the Brahmins, six or more for the other three classes, and the remainder for agriculture. Two or more tanks, or reservoirs, are to be built in every town. Private houses may consist of from one to nine stories; but this is to be determined according to the rank of the persons for whom they are built—the lower classes must on no account construct their houses of more than a single story or ground floor. In front of the houses, on each side of the door, should be erected a "védica," or raised seat, or pedestal.

The Indians employ seven orders of columns, classed according to the proportion between the diameter and the height. The second order, of seven diameters, may be compared with the Tuscan; the third, of eight diameters, with the Doric; the fourth, of nine diameters, with the Ionic; and the fifth, of ten diameters, with the Corinthian: but there is one order of six diameters, and two others from one to two diameters more lofty than the Corinthian. The first two orders of columns are always placed upon pedestals. The general rule with respect to the tapering of the shaft is, that the diameter at the base being divided into as many parts as the shaft is diameters high, the upper diameter is diminished by one of these parts. The higher the column, the less it tapers in proportion, because the apparent diminution of the column is greater according to its height. The plan of the Hindoo column admits of any form—circular, quadrangular, or octagonal; and the shaft is often richly adorned with sculptured ornaments. The intercolumniations have no fixed rule. The capitals do not mark the order, as in those of Greece and Rome, but, on the contrary, they may be varied at pleasure, though not without



Entablature.

regard to the proportion of the column. The profile of the entablature changes little, but the pedestals and bases offer a great variety of outline and ornament. Occasionally, in temples and porticoes, figures of men or animals are carved in bold relief on the sides of pillars or pilasters. The pedestal is frequently employed over cornices, where the edifice consists of several stories, and also as a support for thrones and statues: in the latter situation, great skill has been displayed in their decoration,—nor would they disgrace any period of art in richness of ornament and beauty of proportion. The Engraving, Plate III., shows four of the Indian columns, and a fifth with a lion supporter.

The Hindoos make use of two sorts of cement, or "chunam;" in the interior of the country, it is prepared from a gravelly sort of limestone mixed with sand; and along the coast, from the shells washed out of the salt water marshes—the shell "chunam" is preferred—also mixed with sand; and is mixed with "jaggery-water," a solution of molasses or coarse sugar, the use of which seems to have prevailed from the earliest ages. There is another kind of chunam (not mentioned by Ram Raz), prepared from calcined shells, without any admixture of sand or other foreign matter, and used as plaster: it is tempered with as little water as possible, and well worked-up; when yet moist, it is rubbed, and is susceptible of a high polish.

I shall conclude this lecture with the description of an ancient Indian city, as given in the 'Ramayuna':—"On the banks of the Sarayu is a vast, fertile, and delightful country, called Cosálá, abounding in corn and wealth......In that country is a city, called

Ayodhya, greatly famed in this world, and built by Manu himself, the 'lord of men'......This great and prosperous city was twelve yojanas (nine miles) in length, and three yojanas in breadth, and stored with all conveniences. The streets and lanes were admirably disposed, and the high roads were well sprinkled with water. ......It was adorned with arched gateways, and beautiful ranges of shops; it was fortified with numerous defences and warlike machines, and inhabited by all sorts of skilful artists...... It was beautiful with gardens and groves of mango trees, and inclosed with high walls......It was surrounded by impassable ditches, and secured by fortifications difficult of assault by foreign kings...... It was ornamented with palaces of exquisite workmanship, lofty as mountains, and enriched with jewels; abounding with beautiful houses consisting of several stories; and it shone like Indra's Heaven......Its aspect had an enchanting effect; and the whole city was diversified with various colours, and decorated with regular avenues of sweet-scented trees......It was filled with buildings erected close to one another, and without intermediate voids; and situated on a smooth, level ground......This city truly surpassed any that was ever beheld on earth."

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ARCHITECTURE OF SOUTHERN INDIA.

On the Architecture of Southern India. By JAMES FERGUSSON, Esq., Architect.—(Paper read at the Royal Institute of British Architects, January 7th.)

Those who heard me on a former occasion may recollect that I pointed out, and strongly insisted on the fact, of India being occupied by two distinct and separate races: one of these aboriginal, occupying exclusively at the present day the southern extremity of the peninsula, and extending to and across the valley of the Ganges; but there only as an underlying stratum to a second race. These latter, commonly called the Indo-Germanic or Sanscrit race, came across the Indus from the north-west, and gradually displaced the aboriginal native tribes in the valleys of the Indus and Ganges (except to the extent above pointed out); in these countries they are, and, as far as our histories extend, they always were, the dominant classes. All we know of the literature or history of the country is owing to their superior energy and intellectual development.

The Southern or Tamul races never, apparently, had a literature of their own; most of their dialects are quite uncultivated, and so deficient are their literary records that we know almost nothing of their history or of their intellectual culture. Notwithstanding however this literary and historical poverty, the inhabitants of the south were far more daring and extensive builders than those of the north; and indeed I do not know of any region on the surface of the globe, that can boast of the same number of temples, covering so much ground, and showing such an infinity of labour bestowed on their details; and as such, they certainly deserve to be known and studied.

The principal buildings in the south of India are of course temples, as is the case in most countries, and is always the case in half civilised ones. In this region the temples consist principally of two parts; one of which, called the *Vimana*, is the temple proper—the other, or *Gopura*, is the gateway. There are besides, halls of various dimensions, and walls surrounding the various courts, which I will speak of afterwards. But to begin with the vimana—this consists in all instances of a square basement, of one or two stories in height, ornamented with pilasters, between which are niches containing statues of the gods; within the basement is a square or rather cubical apartment or cella, the sanctum of the temple, in which the principal image of the god is placed. This basement is always built of stone—in the extreme south, an old red sandstone; a little further north, of compact limestone; but over the greater part of the country of a fine close-grained granite. Above the basement rises a pyramidal building, composed of brickwork covered with the fine durable cement of the country, which retains its sharp edge even after the wear and tear of nearly a thousand years. This pyramid consists of one, two, three, four, or more stories, up to twelve or fourteen, according to the dimensions or importance of the building, and is always surmounted by a circular dome-like termination. Each story of the building is ornamented by alternate long and short miniature temples or shrines—alternate vimanas and gopuras in short—each smaller one with at least one image before it, the larger ones with three, or often with groups of a greater number of figures. These smaller shrines, however, though they relieve and vary the surface of the pyramid, are never so important as to break the general outline, which always retains that of a straight-lined pyramid.

The gopura is in every respect identical with the vimana, except that its plan instead of being an exact square is always oblong, generally in the ratio of three to two, so as to admit of its being pierced by the great doorway which always traverses its lesser diameter. The change in the form of the base also necessitates a change in that of the crowning member, which instead of being circular is elongated into a sort of wagon roof, difficult to describe, but easily understood from the drawings. In the mode of decorating it, either architecturally or with sculpture, it is identical with the vimana.

To the vimana is generally attached a porch (or *Mantapa*); frequently this is only a repetition of the basement of the temple, but with a low roof instead of the high pyramidal one of the temple; frequently, however, the porch is open and columnar; in small temples of merely two or four pillars supporting a flat roof, but frequently of thirty or forty pillars, arranged as shown in the diagrams, in a manner which displays the principal peculiarities of the style. Generally speaking the columns are square in plan, changing into octagons and circles, or figures with sixteen sides, according to the rules of Hindoo art, and sculptured from the basement to the bracket capital, which always forms the upper termination, the pillars are generally placed so as to be equidistant from one another all over the floor; but as there is always a wider aisle in the centre running to the door of the temple, and generally a similar one crossing it at right angles, this is obtained by omitting one, two, or even three rows of pillars, and replacing them constructively by attaching bracketing shafts to the fronts of the remaining side columns, and carrying forward from them a bold series of brackets carrying longitudinal ties and trusses, all in stone, till the space to be roofed by flat stones is the same, or nearly so, as that of the side aisles. Besides being used as porticoes to temples, an arrangement similar to this, of one centre and two side aisles on either side of it is used in some temples as a cloister surrounding the courts: at Ramisseram for instance, such a cloister extends for nearly 4,000 feet.

A still more extraordinary columnar arrangement is that of the *Choultries*, or nuptial halls,—usually called "halls of a thousand columns," and frequently containing exactly that number. At Tinevelly for instance, of which a plan is on the wall, the number is easily calculated, as the hall is 10 pillars in width and 100 in length; at Chelumbrum it is 24 × 41, which with the 16 pillars of its porch would make up the number exactly, but there some have been omitted in the centre, so as to allow of open spaces for the ceremonies, so that the actual number is 930; in many instances, however, there are only 600 or 700, but in none that I know of less than 500, and considering that in most cases all these are of granite, generally of one piece from 16 to 20 or 30 feet in height, and always carved from basement to capital with the most varied ornaments, it will be easily conceived what works of labour they must have been, and what impression of infinity of toil they produce on the spectator. I need not here enter into more detail on this subject, but may now proceed to point out how these various component parts of a temple are grouped together, so as to compose a whole.

The simplest and most general arrangement, at least for smaller temples, such as those found in villages, and some of the larger ones, as that for instance at Tanjore, is that of a vimana and its portico standing in the centre of a square court, surrounded by cloisters and inclosed by a high plain wall, with one gopura in front of the entrance to the temple. Few temples, however, except of the smallest class, are of so simple a form, but generally they are surrounded by a second inclosure, the sides of which are parallel to those of the first; say at the distance of about 100 feet. This is likewise surrounded by cloisters, and incloses several minor shrines, or temples dedicated to inferior deities. Generally it possesses two gopuras, the one in front of that belonging to the inner inclosure being generally connected with it by a handsome colonnade or mantapa, with an aisle at right angles to the principal one. The other gopura is placed behind the temple, and is of less importance than the one in front. Almost all the great temples of India possess a third inclosure with four gopuras, one on each face, thus making up seven in all. Besides minor shrines and Brahmins' residences, the outer court generally contains the

great choultrie or hall of a thousand columns; and in this form the southern Hindoo temple may be said to be complete. In some instances a fourth, fifth, sixth, and even a seventh inclosure is subsequently added, and as each of these has a shrine with four gopuras, as in the famous temple at Seringham, a temple may have as many as twenty or twenty-three of these. This however may be said to be rather the exception than the rule; the temple being complete with three courts and seven gopuras. There is however another form, when the temple is dedicated to Siva, of placing two such as I have described side by side, one dedicated to the god himself, the other to the goddess Prava his wife. This is the case at Tinevelly and Madura, in either of which instances there are only eight gopuras, though had the design been carried out as if there were two complete separate temples and three inclosures, the number should have been thirteen, as there is only one temple common to both.

The dimensions of these buildings are very considerable; the outer inclosure, when there are three, seldom being under 500 feet, and ranging from that up to 1000, and even 1200 feet, the usual dimensions being about 600 or 700 feet. The gateways generally are, or are intended to be, in proportion to the length of the wall to which they are attached, thus the inner gateways are generally smaller than the external ones, though not in any exact proportion. In the great temple at Seringham for instance, the inner gopura is quite insignificant, while the outer four attached to the seventh inclosure would, if completed, have been the most splendid in India. Unfortunately they were commenced only in the beginning of the last century, and our wars with the French, and the consequent troubles of the country, put a stop to their erection. The principal one however is a nearly solid mass of granite, 150 feet wide by 100 feet in depth, pierced by a gateway, of 21 ft. 6 in. clear width and about 45 feet in height, roofed with large slabs of granite, 23 or 24 feet in length; had a pyramid of the usual proportion been added to this, it could scarcely have been less than 300 feet in height, which is more than double the usual size of such erections. The materials also, which were used in these gateways, are on the same scale, the door-posts being generally of one slab of granite, 30 or 40 feet in length, and covered with the most elaborate sculpture. The vimanas are seldom on the same scale as the gopuras, and it is one of the principal defects of these buildings, that they want a central point of attraction round which the subordinate ones are grouped. This arose in many instances from a village temple having become sacred, either from some supposed miracle wrought by the god, or some accession of wealth to the foundation—for there as here wealth works miracles—and instead of pulling down and rebuilding the original edifice, inclosures and gopuras were added to the utmost extent the means of the temple would afford.

Another cause was, the mysterious effects produced by the sanctuary not being visible from the exterior: but when you are immediately under the temple, or inside its walls, under its colonnades, the defect is not perceived. While, after passing under its gateways and from one court to another, each more holy and splendid than the last, the effect is certainly grand—when you behold before you the holy of holies, shrouded from human eyes by its high impenetrable walls, and can only peer through its colonnades into the mysterious gloom that shrouds the deity himself. At a distance, however, the defect in an architectural point of view is very striking; and though the number and size of the gateways tell always with striking effect, the mind is ever puzzled and unsatisfied by seeing them all facing different ways, and pointing towards something—and that something is wanting in every view. This, however, is not always the case: at Tanjore, and generally in the smaller temples, or those built on an original and uniform plan, the vimana is the principal object, and the gopuras and mantaps are all in proper subordination to it.

Before leaving this part of my subject, it remains for me to point out some similarities with other styles, which have often been insisted upon by others; and though I myself am not inclined to attach much weight to them, they are still interesting, and others may be inclined to take a different view of the matter from that which I take of it. The first is its presumed identity with Egyptian architecture. In looking, for instance, at the plans of the temples at Karnac or Edfou, we find two or three successive inclosures of high dead walls surrounding the sanctuary. The same and indeterminate number of predominant high massive propyla, which form the only object seen outside; while the sanctuary is low and concealed by the high walls that surround it. The great choultries, besides are both in position and apparently in use similar to the hypostyle halls of these temples; and the propyla are in both instances the great Iconostases, or image-bearing screens of the temple. I may also add, that the same successive mode of erection was, at least in some instances, followed in both cases.

These certainly are strong points of similarity, and at first sight almost conclusive. But on a closer examination they are overpowered by the extreme dissimilarity of design and principle; by the total absence of hieroglyphics, or hieroglyphic expressions, in the Indian examples; and by the utter dissimilarity in every detail between a style so exuberant in strength as the Egyptian, and one so tending to frailty as the Indian. Still, the difference may only be such as exists between the Norman and florid Gothic styles, whose connection no one doubts. It is easier, however, to point out similarities than dissonances, and there are some points in which all masonry styles must resemble one another. It is only by weighing fairly the two styles by one, and by an accurate knowledge of both, that any one can be able to arrive at a just conclusion on the subject. I have myself been so staggered at times by the points of resemblance, that I have been inclined to accede to the general opinion; but on the whole I fear it must be considered in the present state of the question, as too hasty a generalisation.

The similarity that exists between these temples of the south of India, and that at Jerusalem, as described by Josephus, is even more striking and puzzling than that just pointed out; but as it would require large drawings, and more space than I can here afford, to make this intelligible, I will not insist here on what may be after all merely accidental.

It only remains that I should in conclusion say a few words on the general architectural effects of the examples I have been describing. I cannot of course ask you to admire them, nor to agree with me in my estimation of them, for I am aware that to you they must seem both strange and uncouth, if not positively ugly. So at least they appeared to me when I first became acquainted with them, and it was only after I was thoroughly accustomed to their form, familiar with their details, and more than this, thoroughly understood the motives and meaning of every part, that I could see either beauty or design in them. Nor do I think this ought to surprise any one, who recollects how short a time ago it is since every man of taste thought it necessary to characterise the Gothic style as a barbarous jumble of ill-connected incongruities, which our fathers—not even our forefathers—mutilated without mercy, and thought it the greatest merit to hide and obliterate whenever an opportunity occurred. By degrees we came to understand the style, and by deep study of it found out that pinnacles, buttresses, banded shafts, and other peculiarities, which so far from being mere barbarous caprices, were motived elements of construction; and when once we were familiar with the details and understood the construction, all was beauty and order, where only deformity and caprice seemed to exist. So it is with these Indian styles; a man must be familiar with the climate and the people where they are found, must understand their manners and religion, and must familiarise himself with all the peculiarities of the building, before he can either appreciate or admire them. Once, however, he is educated to this, I think he can scarcely fail to perceive beauty, rising sometimes to sublimity, in the immense colonnades, and in the massive propyla and spacious courts of these temples, all of which are constructed on well-defined principles, and all consequently producing the effect the architect designed they should produce on the spectator.

I have learnt to admire these styles in their own country, and do admire them in many respects: but I should be sorry if any one should interpret this expression of admiration on my part as if I were recommending them as models to be transplanted to this country, or as containing anything that could be successfully imitated here. On the contrary, the lesson which the study of these exotic styles seems to me to teach, is diametrically opposed to this, and goes to show that every age and every climate has its own appropriate style, beautiful and appropriate when so used, but absurd and incongruous when either transplanted to another climate, or copied in another age.

Another lesson, which a very slight study of these styles would convey, is the knowledge of the infinity of forms into which stone may be wrought for building purposes. For nearly two centuries all Europe believed that the Roman forms were the only ones capable of producing architectural beauty, and consequently, from the Reformation till the beginning of this century, no other details were used, though their incongruity was frequently ludicrous. Stuart and Revett, and their followers, taught us that we had been copying a corruption, and we in consequence found out that pure Greek details were the only ones worthy of notice. We have now

transferred our affection to Italian and Gothic. A large view, however, of the question, and one to which I conceive the study of the Indian, the Saracenic, the Mexican, and all the other exotic styles would inevitably lead, would show that the forms of architecture are not confined to three or four styles, but are infinite, and so far from being exhausted by those who have gone before us, so as to reduce us of necessity to the mere rank of copyists, as has been often asserted, and would prove we do not yet stand beyond the threshold of invention in this branch; but that new forms spring forward at the bidding not only of every cultivated man who thinks, but even of the savage or the half-civilised man, who tries to express in stone the idea with which he is filled.

The most important lesson, however, that can be derived from the study of these monuments arises from the fact, that they are built by persons who seldom can read or write, and who never can draw, in the European sense of the term at least, and for a people who have neither a written literature nor history of their own,—who have no institutions worthy of the name, and whose religion is one of the grossest superstitions that ever disgraced humanity. Yet these people could invent and perfect a style of their own, which should not only express their own feelings and civilisation, but convey to posterity a higher idea of that civilisation than we can obtain from any other source, and which we with all our cultivation must be content to admire, but have not yet dared to emulate.

Remarks made at the Meeting after the reading of the foregoing Paper.

Mr. Fergusson having concluded his paper, the Chairman, Mr. Scoles, and other Members, put several questions to Mr. Fergusson, who explained, that in nine cases out of ten, all the upper part of the vimana, above the first story, was a mass of solid brickwork. There were small chambers in each story; but they were not used for any purpose, and were obviously made for the object of saving material. Access to them might be obtained by hidden staircases. No skill in construction was exhibited; it was a mere piling up of material. The immense stones used in building the gateways were raised on end or placed across, simply by force of the immense numbers of hands employed. They covered the stone to be raised like ants, and by inserting bamboos after the manner of wedges, literally "shove" it up. He could not use a more dignified term to describe the operation. There was a column 80 feet in height erected at Seringapatam, in memory of Sir David Baird: it was put up in this way. There were no indications of the arch in these sacred buildings.

Mr. Tite.—The lecturer has described this architecture as being of a character *sui generis*, and I am quite of his mind. At the same time I must say that I have been much interested by the beautiful drawings of Central America, prepared by Mr. Catherwood, a member of the Institute: and I have been led by the extraordinary character of the ruins depicted by him, to endeavour to trace the people to whom they are to be attributed. Philological analogies are quite at fault. The language of the people, and that of the other races of India are entirely different. Now I cannot help fancying that I can see a great similitude between the sketches now submitted to us and those of Mr. Catherwood. The Mexican architecture is akin to that of Yucatan, and the characteristics of the latter may be traced in that of Java. It is undoubtedly an immense distance from the south-east point of Hindostan, the architecture of which has this evening so ably been brought before us; and the totally different character of the languages—they having no cognate root—a still greater obstacle. Yet I think this may turn out one of those cases, in which the comparatively imperishable character of architectural remains will aid us more in tracing the connection of races than even philology. Sir Stamford Raffles describes the temples of Java to be pyramidal edifices, like those of Southern India. That is the case also in Mexico, the altar being placed on the top, and the carcases of the victims thrown down the steps. It may be after all, that these resemblances are only those created by the common requirements of a similar climate. I agree with Mr. Fergusson that the supposed resemblance of the Egyptian architecture is not worth consideration. It arose no doubt from the wonder of the sepoys on visiting Egypt; but an uneducated eye would fancy a resemblance, where that of an instructed person would at once decide that there was no real resemblance at all. There is nothing in the architecture of any of these countries to suggest a belief that they are of enormous age. Despite the almost insurmountable difficulties that present themselves, I cannot help thinking that there was a connection between the widely separated races, geographically and philologically speaking, by which these buildings were erected.

Mr. Fergusson.—Javanese architecture is acknowledged to be Hindoo. I know the Hindoo architecture well, and when I was in Java I satisfied myself of the fact. With regard to Mexican architecture, I can only say, that I went carefully over Mr. Catherwood's drawings with him, and we agreed that it had no resemblance to India; all the similarity arises from their being both of a rude style generally, with details most exuberant,—the characteristic of all rude styles. The religion of the Mexicans is totally different from that of India; the latter has no human sacrifices, and in fact no pyramids. They have pyramidal gateways, but altars they have none. In the one case the sacrifices took place always in the sight of the people; in the other the rites are performed secretly inside the temples. In Java, the religion is in fact a branch of Buddhism from the Indian continent.

Mr. Billings thought the models exhibited had a striking general resemblance to the pagodas of the Chinese. We had long prided ourselves in England as the originators of the four-centred arch, but in the drawings now exhibited there it was.

Mr. I'Anson thought the paper just read proved that the subject was one which the government of a great nation like England would do well to take up; particularly as our connection with India was so close. With regard to the architecture before them, he saw in some of it a resemblance to the Greek and even to the Roman tombs.

Professor Cockerell was anxious to acknowledge the great advantage the lecturer had conferred on the Institute, by making known this new family of architecture. It was an interesting fact, that at the extremity of this peninsula there should have arisen a people, whose architecture was so different from all others known. With regard to the peculiar character of the present architecture and its analogies, he must say, that he thought the difference of climate was productive of most of the distinctive features of the styles of different countries. The Jewish temple, for instance, was built in a climate which required those extensive porticoes; and accordingly in the temple there was the inclosure and the portico; and in like manner, in this extraordinary grouping of Indian architecture, a similar arrangement was united, and hence the halls of a thousand columns. Human nature was the same in every climate, and the same feeling which made the shrine of Our Lady at Loretto to be visited by pilgrims from all parts of the Christian world, was traceable in the small temples of India, which, having acquired the odour of a peculiar sanctity, became large temples surrounded by many walls and dignified by many columns. A most instructive study would be that of models of the temples of all religions in the world, by which the similarities of all would be brought out, and their differences traced to their various causes, and particularly in reference to the climate. They had all reason to thank Mr. Fergusson, for the clearness and completeness of the account he had given of this extraordinary architecture.

Mr. Fowler reminded the meeting that one of its honorary members, the Rajah of Tanjore, had presented them with drawings of these very temples. He supported the views of Mr. I'Anson, with respect to the duty of the Government, or of the East India Company, to take up the subject.

Mr. Godwin informed the meeting, that the local papers of India had become strongly alive to the importance of the subject, and the East India Company were doing something for the preservation of these relics of departed generations.

Mr. Fergusson said that the East India Company had taken 40 copies of his work on India, and in consequence of that publication, orders had been sent out to employ persons to make copies of all decaying remains, ere they disappeared altogether. This was done with some ardour until the wars put a stop to the work. Capt. Gill, however, had been three years at work with a large staff, making copies of the celebrated frescoes in the Ajunta Caves. Thirty or forty large paintings, representing the manners and customs of the people during the last 1200 years, had been received at the India House. They were facsimiles of the paintings in the caves. The work was now going on slowly, but would, he hoped, ultimately present a complete illustration of most of the monuments of the past existing in India.

Mr. Papworth inquired whether, as Mr. Fergusson had in his former lecture spoken of five styles, there was any evidence of the duration of each; and whether the character of the religious worship was impressed on the temples. He should also like to know, whether the work of Ram Raz was valuable or not.

Mr. Fergusson said there was no difficulty in determining the age of the works, for the farther they went back the more perfect they were in respect to the carving. The buildings used for temples could not be mistaken for anything else. In the estimation of a native, the newest, the latest built edifice was always the most handsome and the best. That was the chief fault of the work of Ram Raz; but with that exception, and also some geometrical defects in the drawings, the work was valuable. It had however no details to which an European could work.

ENGINEERING PROGRESS.

The Institution of Civil Engineers having elected Mr. William Cubitt as their President, that gentleman, according to custom, has delivered an inaugural address (January 8); wherein he takes a rapid but interesting review of the chief engineering triumphs of the past year, and points out the new fields of usefulness opening up to the inventive powers of man in the mechanical sciences.

After thanking the members for the honour conferred on him, and modestly attributing his election to the fortuitous circumstance of his being "the senior Vice-President in duration of office," rather than to any peculiar fitness on his part, he proceeded to direct attention to some matters relating to the internal policy

of the Institution, and proposed that the evening meetings should terminate at half-past nine o'clock, in order to afford an opportunity for the members and visitors to assemble in the library, and to obtain those personal introductions to each other which constitute one of the great advantages of all societies.

He then announced, that the Council had, with great pleasure, acceded to the recommendation of the last Annual General Meeting, and had invited Mr. Walker, Sir John Rennie, and Mr. Field, the past Presidents, to take their seats at the Council table, in the Council-room, and in the Theatre, as "Honorary Councillors," and that, in future, all those members who should fill the posts of Vice President and President consecutively, holding the latter position for two years, should be considered "Honorary Councillors"; expressing a hope, that the past Presidents might long be spared, to continue that assistance from which the Institution had already reaped so much advantage.

He then announced, that, as the representative of the Institution, he had been nominated a member of the Royal Commission for the promotion of the Exhibition of the Works of Industry of all Nations, under the auspices of H.R.H. Prince Albert, and requested the aid and cordial concurrence of all the members in that "real Peace Congress."

Mr. Cubitt then proceeded to notice the principal engineering works now in progress, or lately completed, as arranged under their respective heads, as follows:—

Tubular Bridges.—Although during the past year there has not been so great a demand for the talents, or the energies of engineers, several remarkable works have been finished, or have far advanced towards completion; I will allude briefly to a few of them, and if others of importance escape notice, it must be attributed to the engineers not having brought accounts of them before the Institution, or even incidentally mentioned them in the discussions. Among these, the tubular bridges across the river Conway and the Menai Straits, are pre-eminent, for the boldness of the conception, the scientific simplicity of the design, and the difficulty of the execution. In tracing the original idea of the most advantageous disposition of a certain amount of material, in a tubular form; the more definite conception of a hollow beam, to permit the passage and support the weight of an engine and train; the experiments for determining the proper distribution of the material, to prevent compression, or disruption; the arrangement for the construction and building up these gigantic masses of material; the means of floating them to their situations, and of raising them to their ultimate destination, at an elevation of 102 feet above the sea (at high water of spring tides);—we must feel justly proud of possessing among us the man whose comprehensive mind could originate this magnificent design, and so successfully perform a portion of the work as to leave no doubt of its ultimate accomplishment. The world already duly appreciates this great undertaking, and we should not be behindhand in testifying our estimate of the bold conception of Mr. Robert Stephenson in the original idea, his professional skill in the design and execution, his care and caution in availing himself of the talents and experience of Mr. W. Fairbairn and Mr. Eaton Hodgkinson, whose scientific investigations respecting the strength of cast-iron, are so well known to the world and so highly appreciated by our profession, and his intrusting the general construction and elevation to Mr. Frank Forster and Mr. Edwin Clarke. Upon the merits of all these gentlemen we may look with pardonable pride and partiality; their labours speak for themselves. However advantageous may be the results of this construction, in facilitating an important communication I shall have occasion to allude to hereafter, it has already been extremely useful in directing attention to the more general employment of wrought iron for the purposes to which it had not previously been deemed applicable; and it will be found that its introduction to structures of all kinds will become more common, exactly as the method of using it becomes better understood.

Report on Iron.—May I here be permitted to diverge for an instant, in order to direct attention to a subject of considerable importance to the profession. In the year 1847 a commission was appointed (of which I was named a member) for the purpose of inquiring into the conditions to be observed by engineers, in the application of iron, in structures exposed to violent concussions and vibration; and for endeavouring to ascertain such principles and forms, and to establish such rules as should enable the engineer and the mechanic, in their respective spheres, to apply the metal with confidence, and should illustrate, by theory and experiment, the action which would take place, under varying circumstances, in the iron railway bridges which had been erected. Numerous witnesses of great theoretical attainment and practical experience, were examined before the commission, and a very interesting series of experiments was carried on, for ascertaining certain points relative to the compression and extension, the tensile and crushing strength, the effect of statical pressure, and of vibration, concussion, &c. The result of this laborious investigation is (in the words of the report, which is now before the public) that 'considering that the attention of engineers has been sufficiently awakened to the necessity of providing a superabundant strength in railway structures, and also considering the great importance of leaving the genius of scientific men unfettered for the development of a subject as yet so novel and so rapidly progressive as the construction of railways, we are of opinion that any legislative enactments with respect to the forms and proportions of the iron structures employed therein would be highly inexpedient.' It would be foreign to my present purpose to enlarge upon the importance of this decision; but I must recommend the Report to your careful perusal and consideration.

The *Harbours of Refuge* now in progress are works of national utility. Those at Dover and in the Channel Islands, by Mr. Walker, deserve particular attention. The former has already produced extraordinary effects on the litoral currents and in the movement of the shingle on the coast, and the latter will afford protection to the storm-driven mariner, where he before expected only danger and death. The Breakwater off Portland Island is important, not only as utilising one of the finest bays on our coast, but also as an immense engineering work, intended to be executed almost entirely by convict labour, and on that account it was necessary to render its construction as simple as possible. This has been achieved by Mr. Rendel, whose design is to form along the site of the intended breakwater a timber staging, carried upon screw piles; on this will be laid railways connected by inclined planes with the quarries on the hill, whence the trains of stones will be brought, and their contents be distributed simultaneously, and in regular thickness over given areas, enabling a careful admixture of large and small materials to be effected, and the whole mass to rise gradually to the surface, and being thus self-supporting, to prevent the washing away of the materials, which has been experienced in other works of a similar nature. The harbour at Holyhead, and the new docks at Leith and at Grimsby, also by Mr. Rendel, do equal credit to his comprehensive designs and his executive skill.

Lighthouses.—In conjunction with these maritime works may be mentioned two lighthouses, both possessing remarkable features. The first is an iron structure, erected on the Bishop's Rock, by Mr. Walker. It is situated about 30 miles from the Land's End, Cornwall, and four miles due west from the St. Agnes Lighthouse, which would probably not have been constructed had our ancestors possessed the modern facilities for the execution of works of this nature. The position is more exposed to the force of the Atlantic than the famed Eddystone Lighthouse, and the surface of the rock is of such an outline as scarcely to admit of a solid building. It was therefore determined to erect such a structure as should offer little or no opposition to the waves, and bear a light at such an elevation as to render it extensively useful. Six hollow cast-iron columns, with a strong bar of wrought iron in each, sunk to the depth of five feet into the rock, forming at the base a hexagon 30 feet in diameter, and tapering upwards, support, at a height of about 100 feet, the dwelling of the three light-keepers, with stores and provisions for four months, the whole being surmounted by the lantern. The access to the dwelling is by a centre column of cast-iron, containing a spiral staircase. The difficulties overcome in the execution of this bold design can scarcely be appreciated without a more detailed account of it, which, however, I trust, will be laid before you during this session.—The other is a stone lighthouse, called the Skerryvore, erected by Mr. Alan Stevenson, on a small desolate rock situated about 11 miles W.S.W. of the island of Tyree, and 90 miles from the mainland of Scotland. The rock is exposed to the fury of the North Atlantic, and is surrounded by an almost perpetual surf. The talent and perseverance of the engineer enabled him, however, to complete, without loss of life or limb—great as were the difficulties he had to contend with—a structure far exceeding the dimensions of the famed Eddystone and Bell Rock Lighthouses, their relative heights being—the Eddystone, 68 feet; the Bell Rock, 100 feet; the Skerryvore, 138 ft. 6 in. The difficulties of the construction, the merits of the structure, and the system of lighting, are so fully described in Mr. Stevenson's published account of it, that it is not necessary for me

to do more than to point to it, as one of the remarkable works of the present day of which we have justly reason to be proud.

In *Steam Navigation* great efforts have been made by some of the principal marine engineers and the builders of wood and iron vessels. The result has been the production of four steamers, with engines by Messrs. Seaward, Miller, Penn, and Forrester, in vessels built respectively by Messrs. Mare, Miller, Thompson, and Laird, for conveying the mails; and an equal number of engines by Messrs. Maudslay and Field, Forrester, and Bury, in vessels by Messrs. Wigram, Mare, Laird, and Vernon, for carrying passengers between Holyhead and Dublin, which have attained the speed of nearly 18 miles per hour, and accomplish the passage, on an average, in four hours. By these means when the Britannia tubular bridge is completed, the journey between London and Dublin may be accomplished within 11 hours. This is an extraordinary advance upon the opinions of only a few years since, when it was reported to be possible to perform the same distance in 14 hours. The excellent machinery of Messrs. Maudslay and Field, and of Messrs. Forrester and Co., in the iron steamers built by Mr. C. Mare and Mr. J. Laird, have also contributed mainly in accomplishing a journey to Paris, as we have recently seen it performed, in eight hours and a half; giving a death-blow to the onerous system of passports, which hitherto interfered so materially with that free and unrestricted communication so essential for the mutual benefit of the two countries. In the accomplishment of this rapid communication with Paris, I may be permitted to feel some pride, as, in my capacity of engineer of the South-Eastern, and in my professional connection with the Boulogne and Amiens railways, the possibility of expediting the intercourse between the two capitals constantly occupied my mind; and so long ago as in June, 1843, before the present fast steamboats were placed on the station, I undertook and accomplished the task of conveying the directors and their friends from London to Boulogne, and home again, between 6 o'clock in the morning and 10 o'clock in the evening, with a sufficient interval for a public reception at Boulogne. Among the builders of steam-vessels, Mr. Scott Russell must be particularly mentioned, for the successful investigation and application of the wave lines to the forms of vessels, so that the curves of least disturbance can at once be adapted to a vessel the ultimate, or greatest velocity of which has been previously determined; and thus high speeds, and easy motion through the water, can be attained; whilst a given immersion is arrived at with certainty. These points were remarkably shown in the *Manchester*, a vessel for carrying passengers across the Humber, at New Holland, and with its consort steamer the *Sheffield*, constructed by Messrs. Rennie, becoming as it were floating bridges, completing the line of the Manchester, Sheffield, and Lincolnshire Railway, and conveying the contents of the trains, from point to point, at a speed of about sixteen miles an hour.

In connection with this railway must be mentioned, the large pontoon, recently built by Messrs. E. B. Wilson and Co. (of Leeds), from the design, and under the direction of Mr. John Fowler. This immense iron vessel, which is four hundred feet long, fifty feet wide, and eight feet deep, with a deck area of twenty thousand square feet, serves as a floating landing stage, for these fast passage-steamers, rendering the railway trains independent of the tide, and of the muddy shores of the Humber.

The deck-area of this landing stage is about half that of a somewhat similar structure, built a short time previous, from my designs, and under my direction, at Liverpool, and of which a description and drawings will be prepared for an early meeting of the Institution; as an earnest of my intention to practise what I have ventured to impress upon all those, who not only possess the information, but the power of imparting it, for the benefit of their professional brethren.

A number of fine steamers have also been constructed, for the Government, for private companies, and for foreign States, in which the beautiful engines of Maudslay and Field, Miller, Seaward, Penn, Napier, Rennie, and others, have fully maintained their European reputation.

Railways.—This incomplete sketch of a few of the engineering works of the past year, leaves untouched that vast subject, the Railway System, towards the completion of which, much has been accomplished within the last twelvemonths, without that public excitement which accompanied all its former progress. There are now nearly five thousand five hundred miles of railway completed in Great Britain, at a cost of about two hundred and twenty millions sterling, which immense sum, derived from private sources, has been expended within the realm, encouraging in an extraordinary degree, productive industry of all kinds, and inducing a revolution in all mercantile transactions and social relations. The Steam Engine and the Power Loom have been regarded by the sober-minded political economist, as the real sources of the power and influence of Great Britain, and though the gallantry of her hardy sons, both in the military and naval services, may have been more publicly apparent, and were, in fact, inestimably valuable when called into action, it is the productive classes of this country that constitute its real strength. The example of England, in boldly abandoning the finest roads, and adopting throughout the length and breadth of the land, a network of iron ways, over which, by the aid of steam, passengers and merchandise are conveyed at a velocity, which, at its first proposition, was by the world deemed worse than visionary, first filled our continental neighbours with astonishment, and then compelled their imitation, so that within a few years, by this new power, the relative positions of the continental states are changed, and the ultimate effect must be to introduce wants, and consequently civilisation, to the most remote corners of the earth.

If this be true, we are naturally led to inquire who were the authors of this great revolution, what minds conceived, and what energies executed these vast projects, thwarted and controlled, as they must have been, by vested interests on the one hand, and the necessity of urging into action a whole nation, before such a momentous change could be effected. The reply, Gentlemen, must spring spontaneously from you all. The Civil and Mechanical Engineers have been the great actors in this most interesting chapter of the social history of our country; and if we may look back, almost with reverence, to the splendid careers of Arkwright, Brindley, Smeaton, Jessop, Mylne, Ralph Walker, Dodd, Watt, Telford, Rennie, and a host of other illustrious names, we may with equal pride look around upon the men of our own time, whose voices have frequently been heard within these walls, instructing and urging us onward in the course they had so successfully followed; some of them are removed from us, but the names of Rennie, Walker, Stephenson, and Brunel, are yet here, and they have left worthy scions to complete the works they so nobly commenced. One great duty the departed have enjoined on us—the record of their works and of our own; and let us remember, that if we desire to hand down our names to posterity, as useful members of society, it is our duty to render this Institution the depository of the accounts of our works, that the future historian of this eventful age, may find in our archives, not only accounts of the works themselves, but of the men who conceived and accomplished them, and to whom their country is so deeply indebted.

For the junior members of the profession, many of whom have already given indications of talent and power, auguring well for their future fame, a wide field is opened in the sanitary question, which embraces the subjects of the drainage and sewerage, the paving, lighting, and cleansing of cities and towns; the more copious and less expensive supplies of water and gas; and, in conjunction with the architects, the improvement of the dwellings of the labouring classes; the establishment of baths and wash-houses; and the introduction of abattoirs.

In this latter portion of the question, the railways should act an important part; for if their establishment has created a wish, or a necessity for travelling, and produced great changes in commercial transactions, by rendering unnecessary the intervention of a third person between the manufacturer and the tradesmen, it would appear feasible to use the same facilities for bringing up from the country large supplies of animal food, ready for sale, instead of the living animals, to be slaughtered in a crowded city, and introducing noxious and unhealthy trades, for using up those portions not fit for food. If, as we have been recently informed by the journals, there be a great discrepancy in the prices of food, between London and the country towns, the aid of the railways should be invoked, and the same producers should be glad to avail themselves of an opportunity of supplying the metropolis, in such a manner as would soon equalise the general prices.

The engineers have always been the real sanitary reformers, as they are the originators of all onward movements; all their labours tend to the amelioration of their fellow-men; and though in times past the introduction of machinery was looked upon with jealousy, education has now happily caused a more just appreciation of their labours; indeed they would deserve the highest encomiums if only for the application of steam, which, in production alone, now represents the power of forty millions of human beings, who, even if they had been able to perform the labour, would have been degraded by it to the level of mere animals, instead of thinking creatures, sent each to perform his part in the complete system of social life.

The heavy demands on the invention and skill of engineers, in the construction of railway works, during past years, have left but little time for the devotion of their energies to the improvement of the mechanical and commercial working of the lines. A wide field is, however, now opened for the exercise of professional skill and ability, in perfecting the applications of tractive power, and all the machinery of railway plant; and it may be reasonably expected, that the opportunities thus afforded to railway companies, of bringing the highest engineering skill of this country to bear upon these questions, may not only produce great economy in the working expenses, and greater efficiency in the general plant, but lead to radical improvements in the construction and maintenance of the destructible parts of the (so called) "permanent way," and thus set at rest the question of depreciation—a desideratum which is now felt to be of almost vital importance to railways as an investment.

I feel, Gentlemen, that, hurried and imperfect as this sketch may be, the subjects have carried me far beyond the limits I had originally intended; and I must request your indulgence for having occupied so much valuable time. You will not, however, find me so trespass upon you again; and, with reiterated thanks for the honour you have conferred on me, I will at once enter on the duties of the office, and proceed to the regular routine of the evening meeting.

MORTON'S IMPROVED PATENT SLIP.

Patent Hydraulic Purchase Machinery, applied to Morton's *Patent Slip, by* Mr. Daniel Miller, C.E., *St. George's-road, Glasgow.*

The great advantages of "Morton's Slip" over all other modes of docking vessels for repairs, &c., in speed, economy, and efficiency, have been long established by the evidence of the ablest scientific authorities, and its practical operation in many ports of the United Kingdom and other countries. The present improvements on it increase these advantages in an eminent degree. They consist in the substitution of improved hydraulic purchase machinery, instead of the system of wheel-work at present in use, and possess the following recommendations:—

1st. That the improved machinery can be laid down for less than one-half the cost of the present machinery; for very large slips much less.

2nd. Ships will be taken up at double the speed, as but a very small proportion of the power is absorbed by friction; and, from the machinery being self-acting, no time is lost by stopping it to take a fresh hold.

3rd. The motion in drawing up a ship is so perfectly smooth and uniform, that no part of the carriage or ship is exposed to any undue strain.

4th. It occupies little space, is not subject to breakage or derangement, and the same foundation does for both purchase machinery and steam-engine.

Description.—The engraving, fig. 1, is an elevation of the purchase machinery, in which A, represents a hydraulic cylinder, fastened securely to a firm foundation at the upper end of the slip. It is fitted with a moveable ram B, working through cupped leathers at the neck. Two side rods, *d*, proceed from a crosshead on the end of the ram, along the sides of the hydraulic cylinder to another crosshead E, where the traction rods are fastened, connecting it with the carriage on which is the vessel to be drawn up on the inclined plane, as represented in fig. 2, on a smaller scale. The traction rods are each of the same length as the ram. F, is the cylinder of a steam-engine with its connecting-rod communicating a rotary motion, by means of a crank, to the shaft *g*. On the shaft are other cranks for giving a reciprocating motion to the plungers of two or more pumps H. A fly-wheel c, on the shaft regulates the motion of the whole.

Fig. 1.

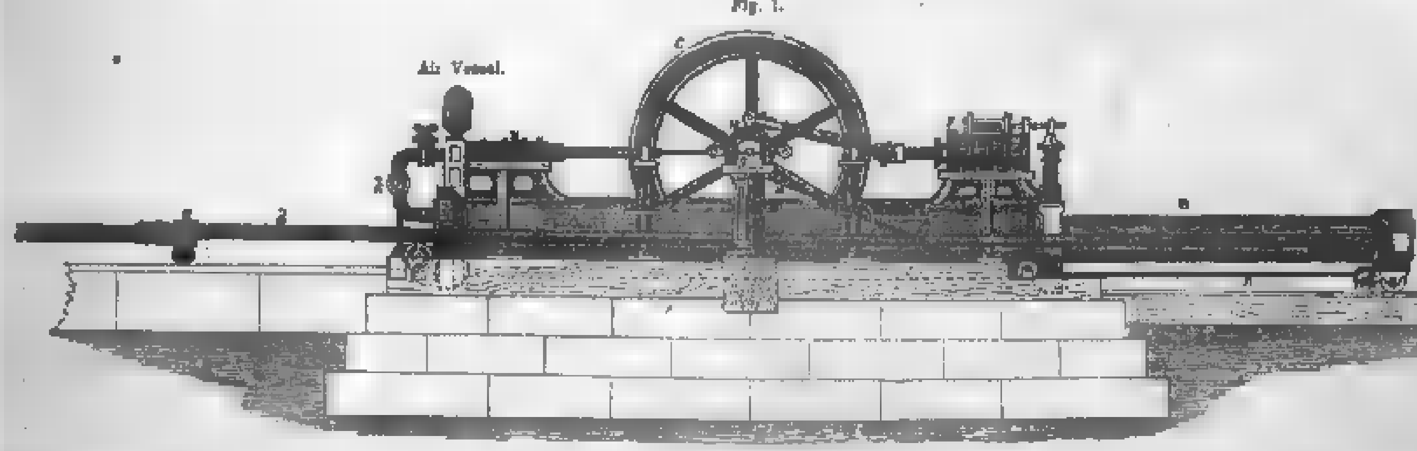
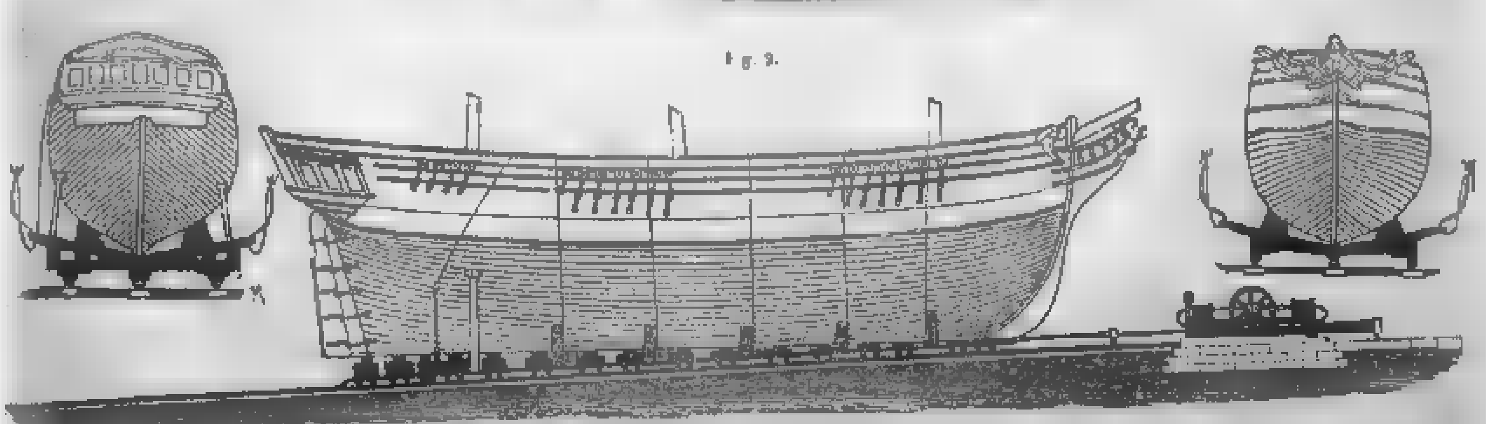


Fig. 2.



Mode of Action.—The carriage having been run down the inclined plane or "slip," the vessel to be taken up is floated on it, and properly blocked up and secured. The lowermost traction-rod of the purchase chain is then attached to the middle or keel-beam of the carriage, and the purchase machinery at the head of the slip is then put in action. The ram of the hydraulic cylinder is supposed to be at the beginning of its stroke, its crosshead being down at the top of the cylinder. By the action of the piston of the steam cylinder F, the cranks on the shaft are made to revolve, putting in motion the pumps H, which abstract water from an ad-

joining reservoir, and force it into the hydraulic cylinder. The ram is thereby made to move steadily up out of the cylinder, with a force in comparison with the steam-engine, as the area of the forcing pumps to the area of the ram; and, by means of the side-rods *d*, communicates the motion to traction-rods connected with the carriage, which, with the vessel on it, is thus hauled up on the rails of the slip. When the ram has moved out of the cylinder to its full extent, or completed its stroke, the traction-rod (being the same length as the stroke) nearest the top is removed. At the same time self-acting apparatus shuts the cock *k*, for admitting water from the pumps into the hydraulic cylinder, and opens another *l*, for the eduction of that which has been forced in, whilst a roller M, on the shaft is put into gear and winds round it a rope or chain *n*, proceeding from the crosshead of the ram, and speedily brings back the ram into the cylinder to its former position, ready to take a fresh hold. The next traction-rod of the purchase chain is now attached to the crosshead E, while the self-acting apparatus is reversing the cocks, and putting the winding-up roller out of gear. The same action as before again takes place, and the ram moves up to the end of its stroke, when another traction-rod is knocked off, and the ram returns to be attached to another. And so on, by a succession of these movements the carriage, with the ship upon it, is steadily and quickly drawn up on the slip to the distance required.

When not employed for hauling up vessels, the steam power may be rendered available for working circular saws, grindstones, and other apparatus required in ship-building yards.

The foregoing represents steam as the motive power employed for working the hydraulic purchase, but, of course, if preferred, manual or other power may be substituted with similar advantages.

GREAT SUSPENSION BRIDGE IN RUSSIA.

Considerable interest has been excited in St. Petersburgh by a remarkable model of a suspension bridge across the river Dnieper, at Kieff, one of the principal cities of Russia. This model was made in London, where it was exhibited to most of the principal engineers and architects. It has since arrived in St. Petersburgh, and has been put up in one of the grand saloons of the Winter Palace, where it was formally presented to his Imperial Majesty on his *fête* day (18th of December), by Mr. Vignoles, the English engineer, from whose designs, and under whose immediate directions, this bridge is now constructing.

The Dnieper is one of the largest rivers in the Russian empire, rising in the vicinity of Smolensko, and flowing in a southerly direction it enters the Black Sea, to the eastward of Odessa. In a broad geographical sense, the Dnieper may be considered as the easternmost boundary between Russia Proper (or Muscovy) and the great kingdom of Poland, which once extended westward nearly to the Giant Mountains of Bohemia, southward to the Carpathians, and northward to the Baltic. The principal city entered by the Dnieper in its long course to the sea is Kieff, celebrated in history as the first spot whereon Christianity was planted among the barbarous hordes then leading a nomadic life over the steppes of Russia, is well known also as an important military frontier post, alternately possessed by the Poles and by the Muscovites, and at present rising into great importance as the capital of the south of Russia.

Kieff is most picturesquely situated on the right or southern shore of the Dnieper; it covers a great extent of space, with numerous public buildings crowning the many heights of the undulating ground on which the city is built. The general aspect of the city is very striking, and the impression on a traveller from the western parts of Europe is that which he would expect to receive on first viewing some Asiatic capital. The commercial part of the town, called the Podol, lies on a low plain at the western extremity; the rest of Kieff is elevated from 200 to 300, and even 400 feet above the level, overlooking all the left or northern shores of the Dnieper, which are low and flat marshes, extending for many leagues above and below Kieff, and from one to two leagues wide. In the spring the whole becomes a lake, as the waters rise; the only approach from the north to Kieff is along a causeway raised above the level of the floods. It is from the end of this causeway that the suspension bridge is thrown across the Dnieper to the foot of the steep acclivities on the right bank. The river, which, for several leagues above, has spread through numerous lateral channels, here unites into one deep bed, and presents the narrowest passage. This passage is, however, still half an English mile in breadth, the depth of the water, in a dry autumn, being upwards of 30 feet in the streamway, and sometimes more than 50 feet after the melting of the snow in spring. Over this chasm, which once formed the barrier for Poland against the invasion of the Muscovites, the necessity of internal communication and the general march of improvement has called for the erection of a permanent bridge, and with enlightened policy the Emperor of Russia has ordered such a bridge to be constructed.

The soil of the bed of the river being wholly of sand, and the current often changing its channel, considerable difficulties presented themselves, while the tremendous breaking up of the ice after winter followed by the melting of the snows in the more northern districts, swelled the stream to an extent scarcely comprehensible to the inhabitants of Great Britain. It became, therefore, a necessary condition that the number of piers of any bridge to be built there should be the fewest possible, with the largest openings between them. Hence it seemed most natural that, with the given limit of expense, the principle of a suspension bridge should be preferred, and the designs were so prepared accordingly, and submitted to his Imperial Majesty. On Mr. Vignoles' urgent recommendations, the use of wire ropes as the means of suspension was negatived, and the adoption of wrought-iron chains with broad flat links was decided on. Such was the system employed for the Menai and Conway bridges in Wales, by Telford; at several places in England; and also in Hungary, at Pesth, across the Danube, by Tierney Clarke. All these bridges, however, have but one central opening. The suspension bridge at Kieff has four principal openings, each of 440 feet, and two side openings of 225 feet each, and also a passage of 50 feet on the right shore, spanned by a swivel bridge, opening for the passage of the steamboats and other river craft. There are, therefore, five suspension piers in the river, one mooring abutment on the left bank, another mooring abutment on the Kieff side of the stream (which, on account of the passage for boats beyond it, is actually an island of masonry in the river,), and an abutment for the swivel bridge on the right bank. Each of these have required a cofferdam of unusual size—particularly the two last mentioned. The architecture of the river piers is rather novel, and of a striking character, harmonising with that used in the extensive range of first-class fortresses which crown the heights of Kieff. The ways through the piers have a clear breadth of 28 feet, and a height of 35 feet to the soffit of the semicircular arches. The platform has nearly 53 feet of extreme breadth, of which 35 feet are exclusively devoted to the carriage-way; the platform is suspended by chains, all on the same horizontal plane, two on each side of the road; the footpaths project beyond the chains, and are carried by cantilevers round the piers exteriorily, so that the foot passengers are completely separated from the horsemen and carriages. The chains are composed of links 12 feet long, and each weighing about 4 cwt.; eight links form the breadth of each chain, and the total length measured along their curves being about four English miles. For the swivel bridge the iron employed is almost exclusively malleable; the breadth of the platform is nearly 53 feet, and the weight of iron employed scarcely exceeds 100 tons. The bridge is moved horizontally (on the same principle that locomotive engines are sent round on the large turntables at a railway station), and by the efforts of four men only, acting on a very simple apparatus. The construction of the platform of the bridge presents several novel combinations of wood and iron, and is of extreme stiffness, to resist the violent action of the eddies of air in violent winds, which have so often injured, and even destroyed, the ordinary platforms of suspension bridges in other places. The balustrade is remarkably light and elegant, in ornamental panels of wrought-iron. Indeed, cast-iron has been carefully excluded from every part of the whole bridge, except where its use was really preferable or absolutely unavoidable. The total weight of iron used in the construction of the bridge is about 3,300 tons, including the machinery used in the various stages of its construction. The whole was made in England, several of the most celebrated ironmasters and manufacturers having been engaged upon it. It required fifteen vessels to bring the iron to Odessa, whence it was taken up to Kieff in small wagons drawn by oxen, over the wild steppes, almost without roads, or none that deserve the name.

The quantity of machinery of every kind employed in the construction of the Kieff bridge is most enormous, and not less than nine steam-engines are in use. Two of these are large stationary ones, each capable of working up to a power of 30 horses; the rest are from four to eight horses' power, and can be moved about as required. These engines pump water, drive piles, grind mortar,

hoist timber, iron, &c., draw loads, and perform a variety of other operations, in substitution of manual labour.

A temporary bridge, carrying a railway, has been thrown across the whole breadth of the Dnieper, and is connected by a self-acting inclined plane with the heights of Kieff, whence the great blocks of granite and masses of iron are sent down from the depôts above to the works on the river. The great provision of granite, bricks, timber, cement, lime, field-stones, &c., is very extraordinary, covering many acres of ground. A whole village of warehouses, offices, shops, sheds, dwelling-houses for the superintendents, and comfortable cottages for the numerous workmen, have been erected on the left bank of the river, on ground expressly raised for the purpose above the flood level. A regular commissariat is attached to the establishment, and the whole organisation of service is very complete. The bricks employed are very hard, and of a beautiful pale colour. Extensive quarries of granite were opened in a great many places, solely for these works; but the principal supply and the largest and finest blocks are found nearly 100 miles from Kieff, and are brought thither on bullock-carts, through a rough country, destitute of roads. Not the least remarkable part of the establishment is that for the manufacture of the hydraulic cement required for the foundations and masonry. It is, in fact, an artificial puzzolano, made from a peculiar clay found in the Kieff hills, and prepared on the principles laid down by the celebrated French engineer, Vicat, in his recent publication. The buildings for this purpose are very extensive, being gigantic laboratories, where the operations are carried on day and night. Eight large roasting ovens, besides numerous grinding mills, are in constant action; the quantity manufactured is upwards of 300 bushels (or about 500 cubic feet) in every 24 hours.

It must be reserved for a technical publication to enter into all the engineering details of construction of the Kieff bridge, as there can only be given here a merely general idea of the principal features of this magnificent bridge, which will be the largest in Europe, the length being fully half an English mile, and covering an area of 100,000 square feet, being considerably more than three acres. The works were first commenced in April 1848. The ceremony of laying the first stone took place in September of the same year. Eight large cofferdams were completed by the early part of 1849; two of these having been destroyed or damaged by the spring floods, have since been entirely reconstructed. The foundations of the abutments and of two of the river piers were safely got in before the winter began, and all the foundations and cofferdams have been secured by an extensive system of protecting works of *mattrasse-fascines*, laid down according to the modern practice in Holland, by Dutch contractors brought purposely to Kieff by Mr. Vignoles. It is expected that the whole of the masonry will be completed by the end of the season of 1850, and that in the course of the autumn of 1851, the Kieff Suspension bridge will be finished and opened.

The causeway approaching the Dnieper from the northward, as before-mentioned, having been greatly damaged in the great floods of 1845, will be put into sufficient repair for the roads on the left bank of the river. On the right bank, a fine new road along the shore at the foot of the acclivities leads up-stream to the commercial and other parts of Kieff, and down-stream to the present ferry and the lower fortresses. Another road will be formed ascending to the great military positions on the heights above.

The beautiful model of this remarkable bridge is on a scale of about $\frac{1}{100}$ of the length of the actual work. It is the most perfect thing of the kind probably ever designed or executed, and reflects the highest credit on Mr. James, of London, the modeller, and his chief assistant, Mr. Sims, who, with another engineer, came purposely from London to erect the model at St. Petersburgh. Every piece of wood or iron, every bolt, screw, and plank—and they are there by thousands—is represented in miniature and in the most perfect manner; the architectural details of the masonry, the interior arrangements of the abutments, the moorings, and saddles of the chains, the machinery of the swivel bridge—all are faithfully represented on the proper scale, and in due proportion. The proportionate scale of length being as 1 to 100, that of area is of course as 1 to 10,000, and that of cube as 1 to 1,000,000! and all the smaller pieces of iron are accurately put into the model in the latter proportion. The stand for the model is of mahogany, supported on bronze Ionic pillars, with gold capitals and frieze, forming a splendid piece of furniture, worthy even of the Imperial Palace. The water of the Dnieper is represented by a mirror, which reflects the under side of the platform, and the whole model is covered with a splendid glass case, set in a gilt frame, with a beautiful dome of glass, supported on richly gilt pillars of the Corinthian order; the whole exquisitely chased. The model and stand have required two years to make, and the expense, from first to last, has been fully 6,000*l.* sterling.

The cost of the Kieff suspension bridge, exclusive of the approaches, will be upwards of 400,000 guineas—say about two millions and a half of silver roubles of Russia, and nearly 11,000,000fr., which, though large in amount, may be considered a very low price for so large a work. Mr. Vignoles has already prepared, by command of the Emperor, designs for several other large bridges in various parts of Russia. Some of them have been approved, and others are still under consideration, and designs are in various stages of progress for still more bridges, besides other works; for all of which the iron must be furnished from the English manufactories.—*Times.*

REVIEWS.

A Treatise on the Rise and Progress of Decorated Window Tracery in England. By Edmund Sharpe, M.A., Architect. London: Van Voorst, 1849.

If the passion for mediæval works has had no better results, it has had a good one in this, that it has given us a copious literature for the mediæval styles, and has destroyed the monopoly of the Greek and Roman styles. So long as these latter were the only learned styles, their professors could put forward a magistral claim, and assume the air of superiority without allowing dispute; just as the Greek and Latin languages were called learned, when these alone had a philological organisation. It is always a bad thing when people are saved the trouble of thinking for themselves, and become "*Ullius jurare in verba magistri.*" When once they have taken to themselves a master, and swear in his name, they are, like other dogs, faithful to his service, and snap and snarl at everybody else. So was it with our classic architects—the principles of art were set aside, and the Ionic or Doric canon was flourished as a weapon against any unlucky wight who thought anything could be beautiful or sublime without the Grecian stamp.

It is to be hoped we are getting to a better period, when we shall be neither Ionic, Italian, or Christian-ite sectarians, but shall be able to acknowledge and appreciate the beautiful in art, whether in the Indies, Persepolis, Hellas, or Germania; and having got thereby so much nearer to the right shrine and the true worship, we may be inspired to do something of our own. Everyone who has a true love for art has, therefore, a deep interest in the cultivation of every department of it: the architect should make a saying for himself, that there is nothing architectural which does not claim his sympathy; and the writer should be encouraged who gives us practical information not only as to Greek and mediæval art, but as to the productions of Egypt, Persepolis, and Hindostan. Thus, Layard, Fergusson, and Owen Jones are as great benefactors to the cause of art as Wilkin or Pugin. It is very certain that we want all the energies of the human mind to be successful in the noble study of architecture; and nothing can be so surely detrimental as restriction to any one school or school-book, if we are to have a national school of architecture as we have a national school in everything else. There are few now who are contented to be the lacqueys of the Greeks and Normans—and yet such we are; while in every other pursuit of genius, we have shown ourselves not unworthy rivals of the great men of olden and of later time.

To study any department of architecture properly, as much attention must be paid to constructive peculiarities as to artistic effect; and as this requires a practical treatment, it seems to us, suiting so well the English character, the field of architectural exploration is one in which we are likely to be particularly successful. Indeed, however much the High Dutch have dreamed, the English have with pen and pencil truly done their share of work; and in England, Normandy, Flanders, Dutchland, Italy, Greece, Egypt, Lesser Asia, Assyria, Hindostan, and Mexico, our students have done much for the extension of architectural knowledge.

It is not, however, given to every one to wend his way to the great shrines of art; and though railway travelling has extended the resources of architectural study, a scamper to Rome or to Memphis can hardly be looked upon as greatly conducive to the instruction of the mass. If, however, this is not so, we believe, if they are properly used, there are large means of instruction open to every study, even in the remotest parts of this country, if he will but choose them.

There is hardly a parish church which has not some point of interest to the practical man; and indeed it is from the careful inspection of these buildings by a practical eye, that a few men, more painstaking than their brethren, have put us in possession of the architectural practice of the middle ages, and have enabled us to construct modern works in the mediæval styles in a much more respectable and much truer manner than our imitations of the Parthenon and other classic models. Nevertheless, a few men can do but little of themselves, however hard they work: it is the concentrated energies of the mass which must act to produce any great result; and this can only be attained inasmuch as each member of the profession will look upon himself as an instrument, however humble, for its advancement. The pupil in the country, beginning his early studies, has often opportunities, denied to the most ardent votaries in the great seats of knowledge; and if he diligently takes advantage of the resources of his neighbourhood, he may do very much good to himself and his neighbours.

There is, too, nothing so mean in itself, which as a part of a great whole, when properly studied, does not acquire considerable importance; and, indeed, often the neglect of a trifle destroys the most meritorious exertions devoted to a great building. In the Gothic revivals of the last century, we are much more struck with pain than with pleasure, for the discordance of the details mars the most ambitious designs,—and this much more attributable to want of constructive knowledge, than to want of artistic skill. As the writer now before us reminds his readers, the history of the mediæval styles in England is one of progress; and the experience of many years, and the genius of many men, led to improvements in construction, as much as to variety in design. These escape the mere archæologist or artist, or he sees them only as trifles, the value of which he does not know; but to the practised eye even of a workman, a knowledge of these trifles is the way to the economical and successful prosecution of a restoration or of a new construction.

It is very evident that had we a better knowledge of the constructive details of Greek buildings, we should be much more successful in the imitation of them; neither would so much diversity of opinion prevail upon many questions of interest, as lights, windows, doors, stairs, roofs, polychromy, and so forth. A knowledge which limits itself to broad general features, might have been thought more favourable to the study of the Greek style; but it has not so proved—and perhaps most from this cause, that the groundwork of our knowledge is imperfect, and imperfect in the practical part. On the other hand, we have monuments which present a repertory of mediæval practice; and it will be found that just in proportion to our better acquaintance with these, has been our successful progress. Wren, Walpole, and Dance had the great works of old before their eyes, and yet the towers of Westminster Abbey, Strawberry Hill, and the front of Guildhall are the fruits of their exertions. The restorations of the beginning of this century abound with errors, and we shall have before us a fresh work—that of re-restoration. Mr. Sharpe gives some examples of this.

The careful study of details has given us works on mouldings, fonts, and church fittings, and now on decorated window tracery. Although the subject is so limited, Mr. Sharpe has required for its illustration a volume of text and one of plates; and even yet he has only laid the foundation of his own part, and leaves for other labourers quite enough to fill other volumes. Nearly two hundred engravings are required, to furnish examples from which authorities are deduced,—and yet the writer is neither prolix nor trifling, nor minutely archæological. He gives a sufficient sketch of the history and chronology, to determine the characteristics of style; but, throughout, his attention is devoted to practical construction. From this the workman will benefit as much as the architect.

Inasmuch as the engineer is often too much of a workman, so is the architect often too little of a workman: and yet there is in this country no academy of architecture with so much as a carpenter's shop attached to it. The architect of the middle ages, inasmuch as he practised all the higher branches of art—carving, painting, and music—so was he often skilful as a blacksmith, mason, or carpenter. The necessities of his position as much made him so, as do those of an Indian officer of engineers make him a workman. In a remote part of the country, the architect had to teach and train the workmen, as well as to furnish the plan. This, too, was one great means of architectural progress. Whoever looks at the buildings of the middle ages, is astonished to see how much was then done. There is hardly a parish church in England which was not then built; and yet in parishes which must then have had a smaller population, we have buildings much more massive and expensive than our modern resources enable us to supply.

The monk or ecclesiastic who undertook to build a church, was much more wanting in money-help than the modern patron; but he drew largely on the unskilled labour of the population. The days of idleness incident to agricultural pursuits, instead of being devoted to the alehouse, were claimed for the pious work of church building; and an enlightened instructor trained a willing flock to undertake the several duties, from quarrying the stone to the carving of it and building it up.

We have now to rely upon trained workmen, instead of upon trained architects; and though we are better off than we were, we are far from having reached perfection. We now look with shame upon the carpenter-Gothic windows of good King George's time—and yet perhaps the day is not far off, when the hypercritical eyes of those who follow may point out the failings of our own works. The only bulwark against this is the practical instruction of architects and workmen. While it is an object of ambition to an architect to produce a beautiful piece of tracery, he is often at the mercy of the workman for the realisation of his designs, for even such a detail requires much knowledge and skill.

If Mr. Sharp has done his duty, so have the publisher and engraver; for the work is handsomely and copiously illustrated throughout, in a manner which is well deserving of praise.

We like much the moderate and judicious spirit in which Mr. Sharpe writes; and he gives full assurance that he merits the confidence of his readers. While he has carefully availed himself of the studies of others, he has added largely to the common stock; and has, by his own observations, been able to correct many theories which were founded on erroneous data. The work has, therefore, the best kind of originality in a professional work—an original investigation of the whole subject of inquiry.

Mr. Sharpe classifies tracery into three styles—geometrical, curvilinear, and rectilinear; and not merely determines the essentials of style, but examines the several arches of the window opening, as the window arch, the scoinson arch, and the rear vault; the foliation; and the mouldings. Upon each of these heads he enters into copious explanations. There is, however, one thing we miss—a sufficient index.

We are debarred from entering further into a subject which is so much matter of special detail, though we are tempted by the merits of the author so to do; but we cannot take leave of him without saying that he has written a book well worthy of the perusal of members of the profession, and of the large circle of students of mediæval architecture, its lay and clerical devotees.

Modern Tombs, Part I. By Arthur W. Hakewill.

Some years since we had occasion to notice a work on tombs, and to make some remarks on this branch of art; and we are not sorry to have it again brought to mind by this work of Mr. Hakewill's. In churches, tombs are most commonly one-sided; and as there is no finished back, there is a limited scope for artistic exertion. If, too, a tomb be truly designed, its character is determined by that of the building; and this is another point of restriction. Where not attended to, as it very seldom is, our cathedrals become curiosity shops or museums, in which naked Greeks and negroes besport beneath the canopies and shrines of mediæval architects. The establishment of the cemeteries threw open a new field for the artist, and one in which he has much more freedom. At the same time the architect could fairly claim a participation, and thus the body of skilled labourers has been strengthened.

It is quite true the marble-mason still claims the graveyard as his domain, and leaves many boundmarks of his authority; but there is a greater disposition on the part of the public to encourage architects; and this it is Mr. Hakewill's object to support. Which, however, will become the chief ruler, the architect or the sculptor, will depend very much on the exertions of each.

While architecture gains a new field of display, it further benefits by the necessity imposed upon sculptors of becoming students of architecture, and strengthening thereby that union of the arts, without the observance of which they cannot prosper. Then, too, the architects must learn something of sculpture, or the public will not be satisfied.

At a former period we were obliged to be contented with designs for tombs, and with the promise of what the future was to do for us; but now we have got some earnest of progress, as Mr. Hakewill's book gives examples from tombs already in our cemeteries. This book, too, will give the greater encouragement to artists, as it shows them what has been done, and that they will not labour in vain. Every way, therefore the book is of interest.

At such an early period we are not to expect perfection—we are to be prepared for many faults; but nevertheless we say that many of the examples presented by Mr. Hakewill deserve consideration and praise. The monument to the prize-fighter, Jackson, by Thomas Butler, in Earl's-Court Cemetery, is very praiseworthy, from the boldness of the design. As to the taste of so openly commemorating such a man, it is nothing to us—we cannot help; and most of the victors at Olympia were of the same stamp. Morrison, the hygeist, St. John Long, the back-scratcher, and Andrew Ducrow, the mountebank, have the largest tombs at Kensal-green: but then they paid for them beforehand, and they had a right to do what they liked with their own. Jackson left a large sum for a tomb; and work of art though it is, and encomiastic as are the verses upon it, it is a monument to a prize-fighter, and nothing else. The lion lying on the top, and the naked prize-fighter at each end, are in keeping; and the prize-fighters are prize-fighters, and nothing else: they are no shams—no model men—no ideals; neither Adonis nor Antinous, but prize-fighters, with the disproportions and characteristics of such. The sculptor knows what such a man is, and has carved him accordingly.

Another design which is in Kensal-green—a tomb with an angel in front—is likewise of a sculptural character, and particularly impressive.

The outline of that of Reynold Morgan, in Kensal-green, is very pleasing. It is a composition with a vase, particularly happy in the harmony of the forms.

We cannot say we like so well some of the architectural designs. They show the old leaven of the sham classical, where the mere introduction of a cornice, or some such feature, in a bald design, is made to do duty for taste and simplicity. The conventionality is purely professional; beauty, under the circumstances, there is none, and the result is the erection of a toy-building instead of a tomb. An Egyptian monument, in which Egyptian peculiarities have been carried too far, pleases us no better; and although it may give an example of the Egyptian style, it gives no favourable proof of the powers of the architect.

The work is to be in four quarterly parts, and to embrace fifty designs; and we very much mistake if Mr. Hakewill will not succeed in giving his readers employment and remuneration, as well as a book, if they take the hint to apply themselves to this branch of practice.

The Pictorial Guide to Ripon. By JOHN RICHARD WALBRAN, Local Secretary of the Archæological Institute. Third Edition. London: Nichols and Son, 1850.

Sepulchri, a Romanis Constructi infra Ecclesiam S. Wilfridi in Civitati Riponensi. By W. DOWNING BRUCE, F.S.A., K.C.J. Third Edition. London: Simpkin and Co., 1850.

The Guide-book is interesting both to the antiquary and the architect. It contains a most accurate and entertaining description of the cathedral church of St. Peter, at Ripon, and of the monastic remains of Fountains and Bolton abbeys; likewise an account of the extensive excavations going on at the present time at Fountains (the property of Earl de Grey), under the direction of the author, a well-known antiquary in the north of England,—the research being directed to an hitherto neglected portion of the fabric, the Abbot's house; the result corroborating the assumption of Mr. Walbran, that its site was on the south-east side of the Lady-chapel—in opposition to the received idea that the Zenodochia, on the western side of the cloisters, had been appropriated to this purpose. The whole site of the house has not been excavated, but quite sufficient has been to indicate its extent. The dimensions of the principal apartments are—The great hall, divided into a main and two side aisles by nine columns, 167 ft. 6 in. by 69 ft. 10 in.; the passage leading from the cloister court of the abbey, 15 ft. 7 in. wide; the chief staircase, 6 ft. 7 in. wide; the oratory or chapel (the last portion built), 46 ft. 6 in. by 11 ft. 5 in.; the refectory, 62 ft. by 23 ft. 9 in.; the dale, 11 ft. 3 in. wide. John de Cancia, the abbot, was the builder of the house (1219-47). The character of the building is plain and substantial. The floors of the principal apartments were paved with encaustic square tiles; several patterns are introduced: one of four tiles displays the arms of the abbey, another the lozenge inclosing the rose. The author supposes they were the rejected tiles of some great work which will be hereafter discovered in the abbey.

The object of Mr. Bruce in his pamphlet is to prove a similarity between the famed crypt under the central tower of Ripon cathedral (usually called St. Wilfred's Needle), and Virgil's Tomb, near Naples,—which he proves by giving a plan and section of each. His efforts to connect the two show, at least, that the Saxons had succeeded admirably in imitating the Roman style of architecture. Mr. Walbran has availed himself of Mr. Bruce's researches on this point.

The Banqueting House, Whitehall, designed by Inigo Jones, consisting of an elevation and two sheets of details. By OCTAVIUS HANSARD, Architect. London: John Weale.

These prints are a valuable acquisition to the architect, and do great credit to the labours of Mr. Hansard; all the measurements of the principal elevation have been taken by him at great cost and labour; he was daily to be seen suspended in a car by a rope taking dimensions of the several details. The plates consist first of an elevation geometrically drawn and shaded to a scale of $\frac{1}{4}$ of an inch to the foot, and two plates showing all the details drawn to a scale $1\frac{1}{2}$ inch to the foot, together with all the dimensions in figures.

"The peculiarities of the building," Mr. Hansard observes, "are numerous, and, as in most large works, so in this, the dimensions of similar and corresponding portions do not exactly agree; their difference, however, is not perceptible.

"On a comparison of the original drawings by Inigo Jones* with the structure itself, it would appear that at some period the rusticated basement has been altered, probably on the occasion of a repair; indeed, there can be no doubt of the rustication of the basement of the west front having been originally similar to that of the east."

The following are the general dimensions:—

	Ft.	In.	Ft.	In.
Height of Rusticated Basement			10	$9\frac{3}{4}$
Height of Ionic Column	23	$9\frac{1}{2}$		
Height of Entablature	4	$9\frac{1}{4}$		
Total Height of Inferior Order			28	$7\frac{1}{2}$
Height of Blocking Course	1	2		
Height of Composite Column	22	7		
Height of Composite Entablature	4	$8\frac{1}{4}$		
Total Height of Superior Order			28	$5\frac{1}{4}$
Height of Balustrade and its Plinths			7	$4\frac{1}{4}$
Total Height of Building			75	$3\frac{1}{2}$
Total Length on Plinth Line			121	$2\frac{3}{4}$

* In the Library of Worcester College, Oxford.

Buildings and Monuments, Part V. Edited by G. GODWIN, F.S.A.

These illustrations are so well executed and so pleasing, that we regret the series is drawing towards a close; and we hope, therefore, the encouragement Mr. Godwin has already received is such as to induce him hereafter to undertake another work of the same kind. The engravings are pleasing; and as the book has the advantage of illustrations from Mr. Godwin's pen, it has likewise a professional as well as a popular value.

Rudimentary Treatise—Tubular and other Iron Girder Bridges. By S. DRYSDALE DEMPSEY. London: Weale.

Mr. Dempsey has in this book brought together all the information extant as to the Britannia and Conway tubular bridges; and those of our readers who have already been put in possession of it piecemeal in our *Journal*, may be glad to have this summary of the subject, in which the text and engravings are reduced to a more portable form.

HUTCHISON'S INDURATED STONE.

Mr. Hutchison has been most successful in rendering the soft sandstone, which abounds at Tunbridge Wells and other parts of Kent, perfectly hard and impervious to wet. Its advantages for many purposes are very great. The stone, when in a soft state in the quarry, is shaped or worked to its proper form, as for chimney-pieces, moldings, ashlar, steps, sinks, &c.; and it afterwards undergoes some preparation which renders it equal to the hardest stone. Mr. Hutchison can deliver the prepared indurated ashlar stone in London, ready for setting, at 1s. 6d. per foot cube, and $1\frac{1}{2}$ inch rubbed paving at 6d. per foot. The paving has been submitted to a severe test for three years at Tunbridge Wells. The preparation may be used with great advantage for any soft stone, and even for chalk or plaster: some specimens of plaster figures that were submitted to our inspection were as hard as a piece of Yorkshire stone.

IRON FOR RAILWAY STRUCTURES.

Report of the Commissioners appointed to Inquire into the Application of Iron to Railway Structures.

From the information supplied to us, it appears that the proportions and forms at present employed for iron structures, have been generally derived from numerous and careful experiments, made by subjecting bars of wrought or cast iron of different forms to the action of weights, and thence determining by theory and calculation such principles and rules as would enable these results to be extended and applied to such larger structures and loads as are required in practice. But the experiments were made by dead pressure, and only apply therefore to the action of weights at rest:—On the contrary, from the nature of the railway system the structures employed therein are necessarily exposed to concussions, vibrations, torsions, and momentary pressures of enormous magnitude, produced by the rapid and repeated passage of heavy trains.

These disturbing causes, in smaller degree, have always occurred in structures connected with mill-work or other mechanism. But the effects upon their stability have not been found greater than could be met by increasing the dimensions of the parts without especially inquiring into the exact principles upon which such increase should be made. Thus, we are informed that the dimensions of cast-iron girders, intended for sustaining stationary loads, such as water-tanks and floors, are usually so proportioned that their breaking-weight shall be three times as great as the load they are expected to carry, or in some cases four or five times as great. But when the girders are intended for railway bridges, and therefore subject to much concussion and vibration, greater strength is given to them by altering the above proportions, and making the breaking-weight from six to ten times as great as the load, according to the practice of different engineers. On the other hand, some consider that one-third of the breaking-weight is as safe a load in the latter case as in the former.

As it soon appeared, in the course of our inquiry, that the effects of heavy bodies moving with great velocity upon structures had never been made the subject of direct scientific investigation, and as it also appeared that in the opinion of practical and scientific engineers such an inquiry was highly desirable, our attention was early directed to the devising of experiments for the purpose of elucidating this matter.

The questions to be examined may be arranged under two heads, namely—

1. Whether the substance of metal which has been exposed for a long period to percussions and vibrations, undergoes any change in the arrangement of its particles, by which it becomes weakened?

2. What are the mechanical effects of percussions, and of the passage of heavy bodies in deflecting and fracturing the bars and beams upon which they are made to act?

A great difference of opinion exists among practical men with respect to the first of these questions. Many curious facts have been elicited by us in evidence, which show that pieces of wrought-iron which have been exposed to vibration, such as the axles of railway carriages, the chains of cranes, &c. employed in raising heavy weights, frequently break after long use, and exhibit a peculiar crystalline fracture and loss of tenacity, which is considered by some engineers to be the result of a gradual change produced in the internal structure of the metal by the vibrations. In confirmation of this, various facts are adduced, as, for instance, that if a piece of good fibrous iron have the thread of a screw cut upon one end of it by the usual process of tapping, which is always accompanied by much vibratory action, and if the bar be then broken across, it will be found that the tapped part is a good deal more crystalline than the other portion of the bar. Others contend that this peculiar structure is the result of an original fault in the process of manufacture, and deny this effect of vibration altogether, whilst some allege that the crystalline structure can be imparted to fibrous iron in various ways, as by repeatedly heating a bar red-hot, and plunging it into cold water, or by continually hammering it, when cold, for half an hour or more.

Mr. Brunel, however, thinks the various appearances of the fracture depend much upon the mode in which the iron is broken. The same piece of iron may be made to exhibit a fibrous fracture when broken by a slow heavy blow, and a crystalline fracture when broken by a sharp short blow. Temperature alone has also a decided effect upon the fracture; iron broken in a cold state shows a more crystalline fracture than the same iron warmed a little.

The same effects are by some supposed to be extended to cast-iron.

We have endeavoured to examine this question experimentally in various ways.

A bar of cast-iron, 3 inches square, was placed on supports about 14 feet asunder. A heavy ball was suspended by a wire 18 feet long, from the roof, so as to touch the centre of the side of the bar. By drawing this ball out of the vertical position at right angles to the length of the bar in the manner of a pendulum to any required distance, and suddenly releasing it, it could be made to strike a horizontal blow upon the bar, the magnitude of which could be adjusted at pleasure either by varying the size of the ball or the distance from which it was released. Various bars (some of smaller size than the above) were subjected by means of this apparatus to successions of blows, numbering in most cases as many as 4,000. The magnitude of the blow in each set of experiments being made greater or smaller, as occasion required. The general result obtained was, that when the blow was powerful enough to bend the bars through one-half of their ultimate deflection (that is to say, the deflection which corresponds to their fracture by dead pressure), no bar was able to stand 4,000 of such blows in succession; but all the bars (when sound) resisted the effects of 4,000 blows, each bending them through one-third of their ultimate deflection.

Other cast-iron bars, of similar dimensions, were subjected to the action of a revolving cam, driven by a steam-engine. By this they were quietly depressed in the centre, and allowed to restore themselves, the process being continued to the extent even in some cases of 100,000 successive periodic depressions for each bar, and at a rate of about four per minute. Another contrivance was tried by which the whole bar was also during the depression thrown into a violent tremor. The results of these experiments were, that when the depression was equal to one-third of the ultimate deflection, the bars were not weakened. This was ascertained by breaking them in the usual manner with stationary loads in the centre. When, however, the depressions produced by the machine were made equal to one-half of the ultimate deflection, the bars were actually broken by less than 900 depressions. This result corresponds with and confirms the former.

By other machinery a weight equal to one-half of the breaking-weight was slowly and continually dragged backwards and forwards from one end to the other of a bar of similar dimensions to the above. A sound bar was not apparently weakened by 96,000 transits of the weight.

It may, on the whole, therefore be said, that as far as the effects of reiterated flexure are concerned, cast-iron beams should be so proportioned as scarcely to suffer a deflection of one-third of their ultimate deflection. And as it will presently appear, that the deflection produced by a given load, if laid on the beam at rest, is liable to be considerably increased by the effect of percussion, as well as by motion imparted to the load, it follows, that to allow the greatest load to be one-sixth of the breaking-weight is hardly a sufficient limit for safety even upon the supposition that the beam is perfectly sound.

In wrought-iron bars no very perceptible effect was produced by 10,000 successive deflections by means of a revolving cam, each deflection being due to half the weight which, when applied statically, produced a large permanent flexure.

Under the second head, namely, the inquiry into the mechanical effects of percussions and moving weights, a great number of experiments have been made to illustrate the impact of heavy bodies on beams. From these it appears that bars of cast-iron of the same length and weight struck horizontally by the same ball (by means of the apparatus above described for long-continued impact), offer the same resistance to impact whatever be the form of their transverse section, provided the sectional area be the same. Thus a bar, $6 \times 1\frac{1}{2}$ inches in section, placed on supports about 14 feet asunder, required the same magnitude of blow to break it in the middle, whether it was struck on the broad side or the narrow one, and similar blows were required to break a bar of the same length, the section of which was a square of 3 inches, and therefore of the same sectional area and weight as the first.

Another course of experiments tried with the same apparatus showed, amongst other results, that the deflections of wrought-iron bars produced by the striking ball were nearly as the velocity of impact. The deflections in cast-iron are greater than in proportion to the velocity.

A set of experiments was undertaken to obtain the effects of additional loads spread uniformly over a beam, in increasing its power of bearing impacts from the same ball falling perpendicu-

larly upon it. It was found that beams of cast-iron, loaded to a certain degree with weights spread over their whole length, and so attached to them as not to prevent the flexure of the bar, resisted greater impacts from the same body falling on them than when the beams were unloaded, in the ratio of two to one. The bars in this case were struck in the middle by the same ball falling vertically, through different heights, and the deflections were nearly as the velocity of impact.

We have also carried on a series of experiments to compare the mechanical effect produced by weights passing with more or less velocity over bridges, with their effect when placed at rest upon them. For this purpose, amongst other methods, an apparatus was constructed, by means of which a car loaded at pleasure with various weights was allowed to run down an inclined plane; the iron bars which were the subject of the experiment were fixed horizontally at the bottom of the plane, in such a manner that the loaded car would pass over them with the velocity acquired in its descent. Thus the effects of giving different velocities to the loaded car, in depressing or fracturing the bars, could be observed and compared with the effects of the same loads placed at rest upon the bar.

This apparatus was on a sufficiently large scale to give a practical value to the results: the upper end of the inclined plane was nearly 40 feet above the horizontal portion, and a pair of rails, 3 feet asunder, were laid along its whole length for the guidance of the car, which was capable of being loaded to about 2 tons; the trial bars, 9 feet in length, were laid in continuation of this railway at the horizontal part, and the inclined and horizontal portions of the railway were connected by a gentle curve. Contrivances were adapted to the trial bars, by means of which the deflections produced by the passage of the loaded car were registered; the velocity given to the car was also measured, but that velocity was, of course, limited by the height of the plane, and the greatest that could be obtained was 43 feet per second, or about 30 miles per hour.

A great number of experiments were tried with this apparatus, for the purpose of comparing the effects of different loads and velocities upon bars of various dimensions, and the general result obtained was that the deflection produced by a load passing along the bar was greater than that which was produced by placing the same load at rest upon the middle of the bar, and that this deflection was increased when the velocity was increased. Thus, for example, when the carriage loaded to 1,120 lb. was placed at rest upon a pair of cast-iron bars, 9 feet long, 4 inches broad, and $1\frac{1}{2}$ in. deep, it produced a deflection of $\frac{5}{10}$ths of an inch; but when the carriage was caused to pass over the bars at the rate of 10 miles an hour, the deflection was increased to $\frac{8}{10}$ths, and went on increasing as the velocity was increased, so that at 30 miles per hour the deflection became $1\frac{1}{2}$ inch; that is, more than double the statical deflection.

Since the velocity so greatly increases the effect of a given load in deflecting the bars, it follows that a much less load will break the bar when it passes over it than when it is placed at rest upon it, and, accordingly, in the example above selected, a weight of 4,150 lb. is required to break the bars if applied at rest upon their centres; but a weight of 1,778 lb. is sufficient to produce fracture if passed over them at the rate of 30 miles an hour.

It also appeared that when motion was given to the load, the points of greatest deflection, and, still more, of the greatest strains, did not remain in the centre of the bars, but were removed nearer to the remote extremity of the bar. The bars, when broken by a travelling load, were always fractured at points beyond their centres, and often broken into four or five pieces, thus indicating the great and unusual strains they had been subjected to.

We have endeavoured to discover the laws which connect these results with each other and with practice, and for this purpose a smaller and more delicate apparatus was constructed to examine the phenomena in their simplest form—namely, in the case of a single weight traversing a light elastic bar. For the weight in its passage along the bar deflects it, and thus the path or trajectory of the centre of the weight, instead of being a horizontal straight line as it would be if the bar were perfectly rigid, becomes a curve, the form of which depends upon the relation between the length, elasticity, and inertia of the bar, the magnitude of the weight and the velocity imparted to it. If the form of this curve could be perfectly determined in all cases, the effects of travelling loads upon bars would be known; but unfortunately the problem in question is so intricate that its complete mathematical solution appears to be beyond the present powers of analysis except in the simplest and most elementary case—namely, in which the load is so arranged as to press upon the bar with one point of contact only, or, in other words, the load is considered as a heavy moving point. In practice, on the contrary, a single four-wheeled carriage touches each rail or girder in two points, and a six-wheeled engine with its tender has five or six points in contact on each side. This greatly complicates the problem.

The above smaller apparatus is so arranged as to comply with the simple condition that the load shall press upon one point only of the bar, and is also furnished with a contrivance by which the effects of various proportions of the mass of the bar to that of the load can be examined. From the nature of the problem, it is convenient to consider, in the first place, the forms of the trajectories that are described, and the corresponding deflections of the bar, when the mass of the bar is exceedingly small compared with that of the load.

Having obtained these under different relations of the length of the bridge, its statical deflection, and the velocity of the passing load, we proceed to investigate, in addition, the effect which a greater proportional mass of the bar or bridge has upon the deflections. We have been greatly assisted in this research by a most elaborate and complete analytical investigation by George Stokes, Esq., Fellow of Pembroke College, Cambridge, undertaken at the request of one of the members of the Commission. Unfortunately, the extreme difficulty of the problem has rendered its solution unattainable excepting in the cases in which the mass of the bridge is supposed to be exceedingly small compared with that of the load, and in the opposite case in which the mass of the load is supposed to be small compared with that of the bridge. The examples that occur in practice lie between these two extremes; for in the experiments of the Commission, performed at Portsmouth, with the inclined plane, already described, the weight of the load was from three to ten times that of the bar; but this is a much greater proportion than that which occurs in bridges, partly on account of the necessity for employing in experiments very flexible bars, to render the changes of deflection sufficiently apparent, and partly on account of the great difference of length; for if bars bearing the same ratio of weight to that of the load were employed in experiment, the deflection would become so small as to be scarcely appreciable. This will readily be perceived when it is stated that in a bridge of 33 feet long, a deflection not greater than one-fourth of an inch is usually allowed, which deflection is only $\frac{1}{1584}$th part of its length; whereas in experiment it is necessary to employ deflections of two or more inches. In actual bridges of about 40 feet span, the weight of the engine and tender is very nearly the same as the weight of that half of the bridge over which it passes; and in large bridges the weight of the load is much less than that of the bridge.

Mr. Stokes has shown, that when the inertia of the bridge is supposed small, the trajectories of the load and the corresponding deflection of the bridge depend upon a certain quantity, which he terms β; this quantity varies directly as the square of the length of the bar, and inversely as the product of the central statical deflection (namely, that which would be produced by the load set at rest on the centre of the bridge), and of the square of the velocity with which the load passes over the bridge. When β is small, the increase of deflection due to the velocity of the load becomes very great, so much so that if β be equal to 1·3, the statical deflections are doubled, and are tripled when $\beta = 0·8$; becoming still greater as lesser values of β are taken. On the contrary, greater values of β correspond to small deflections; and it has been shown by our researches that in the cases of real bridges β is rarely less than 14, and is commonly very much greater; and that, consequently, the greatest increase of deflection from velocity would be upon this theory never greater than one-tenth, varying from that to one-hundredth, or less. As β varies directly as the square of the length of the bridge, it is plain that the nine-feet bars of the Portsmouth experiments will correspond to much less values of β than the 20 and 30-feet lengths of actual bridges; while the values of β in the former cases are still further diminished by the greater deflections necessarily employed in experiments, as above explained. It is thus shown that the enormous increase of deflection produced by velocity in the Portsmouth experiments cannot occur with real bridges, since it appears that the phenomena in question are developed to a great extent when the magnitude of the structure is diminished. But these calculations are made upon the supposition that the inertia of the bridge is very small; and experiments made with the small apparatus above-mentioned have shown that while β is less than about unity, the inertia of the bridge tends to diminish the deflection; while, on the other hand, when β is greater than unity (including, of course, all practical cases), the

inertia of the bridge tends to increase the deflections, obtained upon the above supposition. Lastly, the total increase of the statical deflection, when the inertia of the bridge is taken into account, will be found much greater for short bridges than for long bridges. Supposing, for example, the mass of the travelling load and of the bridge to be nearly equal, the increase of the statical deflection at the highest velocities for bridges of 20 feet in length and of the ordinary degree of stiffness may be more than one-half; whereas for bridges of 50 feet in length, the increase will not be greater than one-seventh, and will rapidly diminish as greater lengths are taken. But as it has been shown that the increase *cæteris paribus* is diminished by increasing the stiffness of the bridge, we always have it in our power to reduce its amount within safe limits. Hence in estimating the strength of a railway bridge, this increase of the statical deflection must be taken into account, by calculating it from the greatest load which is likely to pass over the bridge, and from the highest possible velocity. It must be remembered, also, that this deflection is liable to be increased by jerks produced by the passage of the train over the joints of the rails.

We also made some experiments by means of the large apparatus, before mentioned, on curved bars, and these bore much greater weights at high velocities than straight bars; but the deflections of these bars were very great, compared with their length. In drawing attention to these experiments, we would remark that, in actual structures, where the deflections are so very small, the effect of cambering the girders, or of forming a curved pathway for the load, would be of less comparative importance, and might tend to introduce practical inconvenience.

The general impression amongst engineers appears to be at variance with the above results. They, for the most part, state their belief that the deflection caused by passing a weight at a high velocity over a girder is less than the deflection which would be produced by the same weight at rest; even when they have observed an increase, they have attributed it solely to the jerks of the engine or train produced by passing over inequalities at the junction of the rails, or other similar causes.

For the purpose of examining this question, we have submitted two actual bridges to the test of experiment. These bridges, one of which, the Ewell Bridge, is situated upon the Croydon and Epsom line, and the other, the Godstone Bridge, upon the South Eastern line, are both constructed to carry the railway over a road. A scaffold was constructed, which rested on the road, and was, therefore, unaffected by the motion of the bridge, and a pencil was fixed to the under side of one of the girders of the bridge, so that when the latter was deflected by the weight of the engine or train either placed at rest or passing over it, the pencil traced the extent of deflection upon a drawing-board attached to the scaffold. An engine and tender, which had been in each case liberally placed under our orders by the directors of the companies, was made to traverse the bridges at different velocities, or rest upon them at pleasure. The span of the Ewell Bridge is 48 feet, and the statical deflection due to the above load rather more than one-fifth of an inch. This was slightly but decidedly increased when the engine was made to pass over the bridge, and at a velocity of about 50 miles per hour, an increase of one-seventh was observed. As it is known that the strain upon a girder is nearly proportional to the deflection, it must be inferred that in this case the velocity of the load enabled it to exercise the same pressure as if it had been increased by one-seventh, and placed at rest upon the centre of the bridge. The weight of the engine and tender was 30 tons, and the velocity enabled it to exercise a pressure upon the girder equal to a weight of about 35 tons. Similar results were obtained from the Godstone Bridge. We would take this opportunity of mentioning how much we are indebted to Mr. P. W. Barlow and to Mr. Hood for the assistance they afforded us in making these experiments.

We have also to express our obligations to the Astronomer Royal for the advantage of his presence during the above and other experiments, as well as for many valuable suggestions during the progress of the inquiry.

In addition to the above experiments, we have made many for the purpose of supplying data for completing the mechanical theory of elastic beams. If a beam be in any manner bent, its concave side will be compressed, and its convex side extended. An exact knowledge of the laws which govern its compression and extension must precede any accurate general theory of its deflections, vibrations, and ruptures.

The law which is usually assumed in mathematical investigations, and by which the longitudinal compressions and extensions, within certain limits, are assumed to be directly proportional to the forces by which they are produced, although very nearly true in some bodies, is not, perhaps, accurately true for any material.

Experiments have, therefore, been made to determine with precision the direct longitudinal extension and compression of long bars of cast and wrought iron. The extensions were determined by attaching a bar, 50 feet in length and 1 inch square, to the roof of a lofty building, and suspending weights to its lower extremity.

The compressions were ascertained by enclosing a bar 10 feet long and 1 inch square in a groove, placed in a cast-iron frame, which allowed the bar to slide freely without friction, and yet permitted no lateral flexure. The bar was then compressed by means of a lever, loaded with various weights. Every possible precaution was taken to ensure accuracy. The following formulæ were deduced for expressing the relation between the extension and compression of a bar of cast-iron, 10 feet long and 1 inch square, and the weights producing them respectively:—

$$\text{Extension,} \quad w = 116117e - 201905e^2$$
$$\text{Compression,} \quad w = 107763d - 363184d^2.$$

Where w is the weight in pounds acting upon the bar, e the extension and d the compression in inches.

And the formulæ deduced from these, for a bar 1 inch square and of any length, are—

$$\text{For Extension,} \quad w = 13934040\,\frac{e}{l} - 2907432000\,\frac{e^2}{l^2}.$$

$$\text{For Compression,} \quad w = 12931560\,\frac{d}{l} - 522979200\,\frac{d^2}{l^2}.$$

Where l is the length of the bar in inches.

These formulæ were obtained from the mean results of four kinds of cast-iron.

The mean tensile strength of cast-iron derived from these experiments is 15,711 lb. per square inch, and the ultimate extension $\frac{1}{600}$ of the length, and this weight would compress a bar of iron of the same section $\frac{1}{772}$ of its length. It must be observed, that the usual law is very nearly true for wrought-iron.

Many denominations of cast-iron have got into common use, of which the properties had not yet been ascertained with due precision. Seventeen kinds of them have been selected, and their tensile and crushing forces determined. Experiments have also been made upon the transverse strength and resistance of bars of wrought and cast iron acted upon by horizontal as well as vertical forces. These experiments will be found to exhibit very fully the deflections and sets of cast-iron and the defect of its elasticity.

The bars which were experimented upon by transverse pressure, were of sections varying from 1 inch square to 3 inches square, and of various other sections, and the actual breaking weights show that the strength of a bar 1 inch square should not be taken as the unit for calculating the strength of a larger casting of similar metal, although the practice of doing so has been a prevalent one, for it appears that the crystals in the portion of the bar which cools first, are small and close, whilst the central portion of bars 2 inches square, and 3 inches square, is composed of comparatively large crystals, and bars of 3 inches square in section planed down on all sides alike to $\frac{3}{4}$ of an inch square, are found to be very weak to resist both transverse and crushing pressure. Hence it appears desirable in seeking for a unit for the strength of iron of which a large casting is to be made, that the bar used should equal in thickness the thickest part of the proposed casting.

The performance of these various experiments has been greatly facilitated by the permission which was liberally granted to us by the Lords Commissioners of the Admiralty, to make use of Portsmouth Dockyard in carrying on our investigations, in addition to which, however, we found it necessary to hire for several months some premises in Lambeth. This was found requisite for the performance of those portions of the experimental inquiry which had been undertaken by Eaton Hodgkinson, Esq. Although we are aware that, to point out the labours of individual members of the Commission would be impossible, and that it may appear invidious to single one out for praise, we cannot resist the expression of our thanks to the above-named gentleman for the zeal and intelligence with which he has carried out the remarkable series of experiments which are detailed in the Appendix to this Report, and which constitute a large proportion of those which have been already described.

In addition we have obtained, from many of the iron-masters, information respecting the various processes employed by them in the manufacture of their irons, and the effect of such processes

upon the strength and properties of the material produced: and we have also made careful inquiries of civil engineers with respect to the qualities and mixtures of iron preferred by them, for the large castings used in the construction of railway bridges, and to the respective properties of hot-blast and cold-blast iron: this investigation has been greatly facilitated by the liberality and candour with which these gentlemen have communicated to us the results of their experience.

As no map of the kingdom had been constructed representing the districts in which iron is found and worked, we applied to the officers of the Museum of Practical Geology for their assistance, and they caused one to be prepared expressly to accompany this Report, in which the principal furnaces now in blast are shown.

Great differences of opinion exist with respect to the best qualities and mixtures of iron; and, after all, it appears that those employed for large castings depend practically so much upon the commercial question of relative cost that engineers are rarely able to select the very best material. It is generally admitted that engineers have no guarantee that the mixture for which they have stipulated in a contract shall be that used by the founder, and no certain test by which to determine whether a given piece of iron has been manufactured by hot or cold blast. A very good protection appears to be contained in the recommendation of Mr. Fox, that engineers in contracting for a number of girders, should stipulate that they should not break with less than a certain weight (leaving the mixture to the founder), and cause one more than the required number to be cast. The engineer may then select one to be broken, and, if it break with less weight than that agreed upon, the whole may be rejected.

At the beginning of the railway system the bridges were naturally constructed upon similar principles to those which had been already employed for common roads or aqueducts. Some of these ordinary constructions have proved inadequate to sustain the enormous loads and vibrations of railway trains. Some have been considered too expensive; others, as the suspension bridges, have been found wholly unfitted for railway purposes. Moreover, the necessity for preserving the level of a railroad as much as possible, combined with that of passing under or over existing canals, rivers, or roads, has created a demand for those forms of bridges which admit of being kept as low as possible, consistently with the proper headway or passage below; or, in other words, of making the least possible difference of level between the road or stream which the bridge has to carry and that which it has to cross.

From these causes, combined with the innumerable opportunities of building new bridges which the railways have given occasion to, and a constant endeavour to reduce the expense of building them, a variety of new constructions have been proposed and essayed, most of them of great merit and value, while others appear to be of very doubtful stability.

On the whole, the art of railway bridge-building cannot be said to be in that settled state which would enable an engineer to apply principles with confidence. We have therefore thought it our duty to inquire into the present methods of railway bridge-building, to collect in evidence the opinions and practice of the leading members of the profession of civil engineers upon this branch of construction, and especially with respect to the form and proportions of simple cast-iron girders, the practical limits to the employment of such girders, the methods of combining them with the rest of the structure, the various forms of compound girders, the expediency of several combinations of wrought-iron with cast-iron; and, finally, the comparative merits of plain girders, and of other forms in which the principles of the arch, or other methods of giving stiffness, are introduced.

The simplest bridge, and that which admits of the greatest possible headway at a given elevation, is, undoubtedly, the straight girder bridge.

The length of a simple cast-iron girder appears to be limited only by the power of making sound castings, and the difficulty of moving large masses. Thus the practical length has been variously stated to us as 40, 50, and 60 feet. The form resulting from Mr. Hodgkinson's former experiments on this subject is universally admitted to be that which gives the greatest strength; but the requirements of construction compel many variations from it, especially in the ratio between the top and bottom flanges. Moreover the convenience and the necessity of keeping the roadway for rails as low as possible has introduced a practice of supporting the beams which sustain the rails upon one side of the bottom flange. The pressure of the roadway and of the passing loads being thus thrown wholly on one side of the central vertical web of the girder produces torsion (which is not always taken into account in determining the proportions of the girder). The existence of this torsion is admitted on all hands, and various schemes are employed to counteract and diminish it; but the form of a girder that will effectually resist this disturbing force, without incurring other evils, still remains a desideratum.

The requisite length of girders is increased considerably by the excessive use of skew bridges; and it is much to be regretted that difficulties should often be thrown in the way of altering the course of existing roads and canals when the line of a proposed railway happens to cross them at an acute angle. Partly from these causes, and partly from a little indulgence in the pride of construction, skew bridges may be found, of which, from the obliquity of the bridge, the girders are more than double the length that would be required by the direct span of the opening to be crossed.

When the span of the opening or other circumstances render the use of single straight girders unadvisable, straight girders built up of several separate castings bolted together, and sometimes trussed with wrought-iron tension rods, are largely employed, and necessarily with great varieties of construction. By these means the girders may be extended to spans of upwards of 120 feet.

When wrought-iron is combined with cast-iron in the manner of trussing, several difficulties arise from the different expansions of the two metals and the difference of their masses, which causes the wrought-iron rods to be more rapidly affected by a sudden change of temperature than the cast-iron parts. The constant strain upon the wrought-iron tends to produce a permanent elongation, and hence tension-rods may require to be occasionally screwed up. We have sought for opinions and information upon all these questions, and these show that the greatest skill and caution are necessary to insure the safe employment of such combinations. It is not admitted that the vibration of railway trains would loosen or injure the bolts or rivets of compound girders. Nevertheless, wood, felt, or other similar substances have occasionally been introduced between surfaces to diminish the communication of vibration.

The general opinion of engineers appears to be that the cast-iron arch is the best form for an iron bridge when it can be selected without regard to expense or to the height above the river or road which is to be crossed. For low bridges the bowstring girder is recommended. Lattice bridges appear to be of doubtful merit.

The latest mode of construction that has been introduced consists of boiler plates riveted together as in iron ship-building, and combined in various ways with cast-iron. Hollow girders are thus formed, which are either made so large as to admit of the road and carriages passing through them, as in the Conway and Britannia bridges, or else these tube girders are made on a smaller scale and employed in the same manner as the ordinary cast-iron girders, to sustain transverse joists which carry the road. The first kind is applicable to enormous spans, those of the two bridges above mentioned being 400 and 462 feet respectively. The second kind are said to be cheaper and more elastic than other forms for spans that exceed 40 feet. These methods appear to possess and to promise many advantages, but they are of such recent introduction that no experience has yet been acquired of their powers to resist the various actions of sudden changes of temperature, vibrations, and other causes of deterioration. We have thought it our duty to seek for information with respect to them, and we find engineers to be for the most part exceedingly favourable towards them; but for the reasons above stated we are unable to express any opinion upon them. At the same time we desire to bear testimony to the patient care and scientific manner in which the forms and proportions of the great tubes of the Conway and Britannia bridges have been elaborated; and we must beg to refer to the Minutes of Evidence for the details of the information which we have collected.

The investigation in which we have been concerned has made it evident that the novelty of the railway system has introduced a variety of new mechanical causes, the effects of which have not yet had time fully to develope themselves, on account of the extent and number of new railways, and the rapidity with which they were constructed, in many cases scarcely giving breathing time to the engineers, by which to observe and profit by the experience of each successive new construction. Thus it has happened that some portions of mechanism and structure have been made too weak, or placed in unfavourable combinations; and hence some unavoidable but most lamentable, and sometimes fatal accidents, have been occasioned. It also appears that there exists a great want of uniformity in practice in many most important matters relating to railway engineering, which shows how imperfect and deficient it yet is in leading principles.

But we have also observed throughout the present inquiry that the engineers have been already warned by experience of the necessity for increasing the strength of bridges employed in railways; and of watching more narrowly their construction, so as to render them as strong as possible. Accordingly we have found that the original structure of all those bridges which had shown the least signs of weakness, has been carefully altered and strengthened, so as to leave no apparent cause for apprehension; while in new bridges, better and stronger combinations are adopted.

And in conclusion, considering that the attention of engineers has been sufficiently awakened to the necessity of providing a superabundant strength in railway structures, and also considering the great importance of leaving the genius of scientific men unfettered for the development of a subject as yet so novel and so rapidly progressive as the construction of railways, we are of opinion that any legislative enactments with respect to the forms and proportions of the iron structures employed therein would be highly inexpedient.

We would, however, direct attention to the general conclusions we have arrived at from our own experiments and from the information supplied to us, namely,—

That it appears advisable for engineers in contracting for castings to stipulate for iron to bear a certain weight instead of endeavouring to procure a specified mixture.

That to calculate the strength of a particular iron for large castings the bars used as a unit should be equal in thickness to the thickest part of the proposed casting.

That, as it has been shown that to resist the effects of reiterated flexure iron should scarcely be allowed to suffer a deflection equal to one-third of its ultimate deflection, and since the deflection produced by a given load is increased by the effects of percussion, it is advisable that the greatest load in railway bridges should in no case exceed one-sixth of the weight which would break the beam when laid on at rest in the centre.

That as it has appeared that the effect of velocity communicated to a load is to increase the deflection that it would produce if set at rest upon the bridge; also that the dynamical increase in bridges of less than 40 feet in length is of sufficient importance to demand attention, and may even for lengths of 20 feet become more than one-half of the statical deflection at high velocities, but can be diminished by increasing the stiffness of the bridge; it is advisable that, for short bridges especially, the increased deflection should be calculated from the greatest load and highest velocity to which the bridge may be liable; and that a weight which would statically produce the same deflection should, in estimating the strength of the structure, be considered as the greatest load to which the bridge is subject.

Lastly, the power of a beam to resist impact varies with the mass of the beam, the striking body being the same, and by increasing the inertia of the beam without adding to its strength the power to resist impact is within certain limits also increased. Hence it follows that weight is an important consideration in structures exposed to concussions.

Whilst, however, we lament that the limited means which have been placed at our disposal, and the great time required for such investigations, have compelled us to leave in an imperfect state, or even to neglect altogether, many interesting and important branches of experimental inquiry, we trust that the facts and opinions which we have been enabled to collect will serve to illustrate the action which takes place under varying circumstances in iron railway bridges, and enable the engineer and mechanic to apply the metal with more confidence than heretofore.

Whitehall, 26th July, 1849.

WROTTESLEY.
ROBERT WILLIS.
HENRY JAMES.
GEORGE RENNIE.
W. CUBITT.
EATON HODGKINSON.

DOUGLAS GALTON,
Lieut. Royal Engineers,
Secretary.

Analysis of the Evidence received by the Commission.

Chemical Constituents of Iron.—Mr. Morries Stirling states, that iron in its pure state is malleable, and that it is a combination of carbon with iron which produces cast-iron. In addition to carbon, the cast-iron in this country contains silica, lime, magnesia, alumina, occasionally some of the phosphates and other admixtures; but iron made from magnetic ores is much purer. The strength of cast-iron depends upon its freedom from impurities and upon the proportion of carbon it contains. The strongest cast-iron contains about three per cent. of carbon, or, according to Mr. Charles May, when the carbon is in the smallest proportion that produces fluidity, a larger proportion tends to make the iron soft and weak, and a smaller hard and brittle. Mr. Glynn states, that the strongest iron generally shows a clear grey, or slightly mottled fracture, and he considers that that colour indicates the combination of carbon with iron which produces the greatest strength. Mr. Morries Stirling states, that while colour is admissible as a test of strength it is not so of chemical constitution, for though dark-coloured iron is usually weak, grey iron usually strong, and white iron usually brittle, yet black iron when chilled becomes white, although it must be supposed to contain the same quantity of carbon; hence, as a general rule, he concludes that colour indicates the treatment to which iron has been subjected, and in some cases only the quantity of carbon. Mr. Charles May coincides in considering the question of strength to be very much reducible to the quantity of carbon contained in the iron, as some of the tenderest iron skilfully treated will produce some of the strongest castings. Mr. Stephenson and Mr. Morries Stirling mention that the fluidity of the Berlin iron is due to the presence of arsenic, and the latter has observed that manganese mixed artificially with cast-iron closes the grain and is an improvement both to cast-iron and steel. On wrought-iron the effect of manganese is stated to be to give it the hot short property, whilst the cold short is produced by the presence of a small quantity of phosphorus; and the admixture of arsenic renders wrought-iron hard and brittle.

Qualities and Mixtures of Iron.—The use of the *hot-blast* in the manufacture of iron, it is stated by Mr. Glynn, does not of itself make iron worse or better; but by its means, materials, otherwise intractable, yielding alloys of iron may be smelted, instead of ores yielding purer metal. Mr. Morries Stirling has not found any distinct difference between the chemical constituents of hot-blast and cold-blast iron, but apparently there is more carbon in the hot-blast iron, and graphite is more commonly to be seen on the surface of No. 1 hot-blast than on cold-blast iron. Mr. Charles May considers, that by the use of the hot-blast the quantity of carbon which can be combined with the iron is increased. Mr. Hawkshaw and Mr. Fairbairn consider hot-blast iron weaker than cold-blast; the latter gentleman and Mr. Stephenson state that the use of the hot-blast renders the metal very fluid; and Mr. Glynn says that its use is to produce in large quantities and at a cheap rate a soft fluid metal to be employed in light castings, and that in that respect he considers the invention to be of great public benefit, as enabling Scotch iron-masters to use a new kind of ore, which though of a weaker character, further experience may enable them to purify and improve.

At the same time the hot-blast is essential for smelting the iron-stone from South Wales with anthracite coal, and the metal yielded is of the strongest character. Mr. Glynn and Mr. Stephenson mention that generally hot-blast iron is dark grey in colour and very fine in the crystal; but it appears to be universally agreed that there is no certain method of distinguishing hot-blast from cold-blast iron. Mr. Rastrick states that the temperature of the hot-blast at the Gartsherrie furnaces was 680° Fahrenheit.

Mr. Stephenson does not attach much importance to the variation in strength of different sorts of iron, he considers that taking the average of irons generally throughout the country there is a proximity to an uniform standard. He concludes, from a series of experiments made by him for the High Level Bridge at Newcastle, that hot-blast iron is less certain in its results than cold-blast; that mixtures of cold-blast are more uniform than those of hot-blast; that mixtures of hot and cold-blast give the best results; that simple samples do not run so solid as mixtures; that simple samples run too hard and sometimes too soft for practical purposes. Mr. Rastrick would prefer making girders of forge iron. Mr. Hawkshaw would use the Lowmoor iron. It is, however, generally admitted that mixing irons from different parts of the country produces the best castings, and since the object in mixing them is to obtain the proportion of carbon to iron which gives the greatest strength combined with the required degree of fluidity, the exact proportion will be regulated by the appearance of the fracture of the several irons. Mr. Morries Stirling states that No. 1, hot-blast iron, mixed with No. 3, cold-blast, will give the right proportion of carbon; but that if iron containing that proportion could be obtained at once from the blast-furnace, it would be very superior. Mr. Charles May, however, observes, that the strength of cast-iron depends upon the bulk into which it is to be run as well as upon its constituent parts, and that the art of the ironfounder consists in his ability to produce the required amount of strength without any very definite knowledge upon the subject, either chemical or mechanical. Mr. Fox considers a very good mixture for girders to be cold-blast Blaenavon, two-thirds, and of hot-blast Scotch two sorts, from the black band and the red hæmatite ores, one-third. Mr. Grissell considers the use of old scrap iron to be of immense value, and would use Scotch iron, cold-blast Welch, and old scrap. Mr. Fairbairn names as the best mixture independently of price—

Lowmoor, No. 3	30	per cent.
Blaina, or Yorkshire, No. 2. . .	25	,,
Shropshire, or Derbyshire, No. 3 .	25	,,
Good Old Scrap	20	,,
	100	

Mr. Glynn names one-third strong iron from South Wales and two-thirds of the more fluid metal of Yorkshire, Derbyshire, and Shropshire. Mr. C. Fox, Mr. Grissell, and Mr. Charles May, however, all concur in stating that mixtures of iron practically depend very much upon the commercial question of cost, and it is generally admitted that engineers have no guarantee that the mixture for which they may have stipulated in a contract shall be that used by the founder; hence Mr. Fox recommends that engineers in contracting for a number of girders should stipulate that they should not break with less than a certain weight (leaving the mixture to the founder), and cause one more than the required number to be cast; the engineer might then select any one to be broken, and if it broke with a less weight than had been agreed upon, the whole should be rejected. Mr. Glynn considers that the strongest castings are those cast from the air-furnace in dry sand, and castings in loam are stronger than those in open sand. The metal is more dense and more free from impurity when cast upright. Mr. Fox and Mr. Fairbairn also prefer the air-furnace. With respect to wrought-iron, Mr. Morries Stirling considers the process adapted in its manufacture as capable of great improvement. Mr. E. Clarke states, that wrought-iron from the same maker is not always the same, and though there is not much difference in the ultimate strength of iron, that some qualities extend much more than others before breaking.

Proportion of Load to Breaking Weight, in Girders.—There appears to be a considerable difference of opinion as to the proportion between the greatest load which a girder should be allowed to bear and the breaking weight. There are two conditions under which the weight may be applied, viz., first, when stationary, as in the case of water-tanks, floors, &c.; second, when the weight moves so as to cause concussions and vibrations, as in railway bridges. In girders required for the first case Mr. Fox and Mr. T. Cubitt consider that the breaking weight should be three times the greatest load; Mr. P. W. Barlow four times; and Mr. Glynn would not make it less than five times the load.

In girders for railway bridges Mr. Brunel states that he allows the load to be one-third or two-fifths of the breaking weight; but he considers that the rule he adopts for calculating the dimensions of his girders gives more than the usual strength. Mr. Grissell and Mr. Charles May consider one-third to be sufficient; Mr. Rastrick, Mr. P. W. Barlow, Mr. R. Stephenson, and Mr. Joseph Cubitt adopt one-sixth; Mr. Hawkshaw prefers one-seventh, except in cases where great care is exercised in the selection of materials and workmanship, when a smaller proportion would suffice; and Mr. Glynn considers that in structures exposed to concussion and vibration the ultimate strength of a girder should be ten times the greatest load.

Tests for Girders.—The general opinion as to the amount of test which should be applied to girders is that the test should amount to twice the greatest load. Mr. Joseph Cubitt would employ three times the greatest load, or half the breaking weight; and Mr. Thomas Cubitt considers it safer to test a girder almost to the extent that would break it than not to prove it at all, as the testing of girders is the only means of discovering defects under the surface, and concealed from the eye. Mr. Brunel, however, thinks that a girder should not be tested with a weight exceeding the greatest load, as the object in testing is to ascertain the soundness of the casting, which may be judged of by its appearance under the load, and all risk of permanent injury should be carefully avoided. Mr. Rastrick, Mr. Glynn, and Mr. Joseph Cubitt recommend that blows be applied to cast-iron girders when under the testing load. Mr. Hawkshaw and Mr. P. W. Barlow consider that where actual weight is used sufficient vibration is given to the beam by throwing the weight into the scales used in testing. It is stated that, for convenience sake, girders are usually tested by means of the hydraulic press; but Mr. Fairbairn, Mr. Locke, Mr. Brunel, Mr. Joseph Cubitt, and Mr. Fox prefer using actual weight, on account of the uncertainty as to the actual pressure the hydraulic press brings upon the girder; though the latter gentleman considers that all liability to error in the press is obviated by an improved construction which he has adopted. Mr. C. May states that, as girders are bought at the lowest possible price per ton, the manufacturer is compelled to adopt the most convenient and not the best mode for testing them, or ten times his profit would not pay him for the experiment.

Loads on the Bottom Flange.—It is admitted that the mode of supporting the roadway on the bottom flange of a girder causes torsion in the girder, though Mr. Rastrick and Mr. Locke do not consider that the strength is diminished by the pressure being so applied; and Mr. Stephenson does not think the torsion is of sufficient consequence to be noticed. In order to guard against any ill effects which might arise from the torsion, Mr. Locke fits in transverse pieces of timber between the two girders which support a line of rails, chocked perfectly tight, and he ties the bottom webs together with tension bars. Mr. Fairbairn and Mr. Hawkshaw consider it would be advantageous to alter the form of girders to enable them to withstand the torsion. Mr. Fairbairn thinks the cross beams should either lay on the top flange, or be suspended by hook bolts from the bottom flange, in which opinion Mr. Glynn concurs. Mr. Hawkshaw would increase the top flange of the girder, or would cast shoes or brackets on them to bring the bearing of the transverse joists close to the vertical web. Mr. P. W. Barlow has adopted a new form of bridge to avoid this torsion. Mr. W. H. Barlow observed considerable torsion in a girder without any top flange. Mr. Fairbairn and Mr. Hawkshaw are of opinion that wooden cross-bearers for the roadway are liable to increase the amount of torsion by bending; but Mr. Stephenson and Mr. Brunel state that wood is desirable as a cushion to prevent the noise and vibration which iron on iron would be subject to.

Length for Simple Cast-Iron Girders.—The use of simple cast-iron girders in bridges appears to be limited only by the power to make sound castings (which arises chiefly from the difficulty of pouring the metal equally, and the inconvenience of handling large masses. Mr. Rastrick, however, would not put any limit to the length. Mr. Hawkshaw considers that they may safely be made more than 50 feet long; in which opinion Mr. Fox and Mr. Grissell concur, but name 60 feet as the limit. Mr. Glynn, Mr. Charles May, and Mr. Joseph Cubitt would make them from 40 to 50 feet. Mr. P. W. Barlow, Mr. Fairbairn, Mr. W. H. Barlow, and Mr. Stephenson state 40 feet as the limit; and Mr. Brunel names 35 feet, as he does not consider that sound castings can be ensured to a greater length. Mr. Fairbairn, however, mentions a girder in Holland 70 feet long cast in one piece.

Form for Simple Girders.—It appears to be universally admitted that the form resulting from Mr. Hodgkinson's experiments on the tension and compression of iron is that which gives the greatest strength; but the actual proportions are generally modified to suit the varying circumstances under which girders are employed. Mr. Stephenson sometimes makes the top flange equal to the bottom one, but usually in the proportion of 3 : 5, partly to obviate any risk from unequal cooling of the materials, and partly from the necessity of having a large top flange to bolt the flooring to. In preference to using a single girder, Mr. Stephenson recommends two girders to be bolted together, with a baulk of timber between, to which the rail is fixed. Mr. Hawkshaw, Mr. Fox, and Mr. Joseph Cubitt recommend that the top flange be increased beyond the proportions given by Mr. Hodgkinson, in order to resist the lateral torsion. Mr. W. H. Barlow and Mr. Locke would use the arched form of girder whenever practicable, and the former gentleman says that straight girders have been in fashion, and consequently more used than practice actually required. Mr. Fox, in girders subject to dead weight only, would make the proportion of the top flange to the bottom one as 1 : 6; but in railway bridges he recommends 1 : 4. Mr. Thomas Cubitt mentions that shoes, or sockets, or any projections cast on girders, have a tendency to create flaws from causing the dirt to accumulate in those places, and he considers that the shape which will ensure a sound casting should be as much considered as the theoretical form of greatest strength.

Deflection of Girders, and Effects of Permanent Loads and Change of Temperature.—It is considered that girders should not deflect more than from $\frac{1}{300}$th to $\frac{1}{400}$th of their length according to the form of the girder. It does not appear from the evidence that a weight equal to what a girder is constructed to carry will, even if left on for any length of time, cause the deflection of the girder to increase, unless subjected at the same time to considerable changes of temperature. Some experiments made by Mr. Fairbairn and Mr. Braidwood show that iron loses a considerable proportion of its strength when heated to a temperature of more than 220° Fahrenheit, and that it becomes uncertain below 32°. Mr. Clarke described the effect of the sun coming out and shining on the Conway tubular bridge for half an hour to have been to raise the tube vertically one inch; and he mentions that at night, from the low temperature, the deflection was always greater than in the day-time. Mr. Fox instances the effect of frequent and great changes of temperature on some short girders, 6 feet long, which support the hoods of the forges in his workshops. In the day-time they are so warm that the hand can only just bear the heat; at night they become cold. The effect is to make the girders *swag*, and the swagging appears to be continually increasing. Some have attained as much as 3″ deflection in the centre; but their strength does not seem to be impaired.

The general impression of engineers appears to be that the deflection caused by passing a weight at a high velocity over a girder is less than the deflection which would be produced by the same weight at rest; and the increase observed, in many instances, is attributed by Mr. Locke, Mr. Stephenson, and Mr. Fox, to the inequalities at the junction of the rails, or to the jerks of the engine. Mr. Hawkshaw however considers, that the deflections would be increased, and has given some examples of a manifest increase.

Mr. P. W. Barlow has observed a slight increase, and Mr. W. H. Barlow, in reference to this subject, cites a curious phenomenon which he observed on a timber viaduct, viz.: that with a heavy goods train at a low velocity, a certain amount of deflection was produced; but an express train passing immediately afterwards, with a much lighter engine, seemed to push the bridge like a wave before it.

Forms of Girders beyond the limits of simple Cast-Iron Girders.—The modes of construction which have been adopted by engineers for crossing spans beyond the limits of girders made of a single casting, are very various; but the chief forms which have been adopted by engineers for girders of a compound nature in railway bridges may be classed under straight built-girders of cast-iron in separate pieces bolted together; arched girders of cast-iron; trussed girders; bow-string girders; wrought-iron box and tubular girders.

The Built Girder is formed of separate castings fitted closely at the joints and bolted together, and is entirely dependent upon the bolts for support. Mr. Grissell instances one of 120 feet span, and states that he should have

no hesitation in making one of 200 feet span; but the engineers generally seemed to consider that other modes of construction disposed the material more advantageously. Mr. P. W. Barlow exhibited a new form of girder in separate castings, for moderate spans.

The Arched Girder.—The cast-iron arch is a mode of construction which all engineers concur in approving of, when not limited by considerations of levels or of abutments. Mr. Locke states he would never willingly use cast-iron in any other shape than that of an arch. Mr. W. H. Barlow has also adopted it where practicable.

The Trussed Girder is straight and of separate castings bolted together, assisted by wrought-iron tension rods. The Dee Bridge girder was on this principle. Mr. Stephenson caused an experimental girder to be made, to exhibit the effect produced by the tension rods, adjusted as they were in the Dee Bridge girders, as well as the effect when adjusted to lie parallel with the bottom flange and adjoining it; these experiments, in conjunction with some made by Mr. T. L. Gooch, show that the tension-rods, though th eydo not, when acting at the angle, as they did in the Dee Bridge girders, produce the full effect; yet, that they add considerably to the strength of the girder. Mr. Rastrick and Mr. Fairbairn object to the trussed girder on account of the different rates of expansion in cast and wrought-iron. Mr. Stephenson and Mr. Wild propose to obviate this objection by putting the tension-rod along the bottom flange, and applying to it an initial strain of five or six tons per square inch, so as to cause the wrought-iron to come into play as soon as any weight is applied to the girder. Mr. Fox approves of this arrangement, but he considers that a strain upon wrought-iron tends to stretch the metal permanently, and that the tension-rods would require to be tightened periodically, whilst Mr. Stephenson and Mr. Wild have concluded from their experiments, that with a less weight than ten tons per square inch, the elasticity of the metal is not affected. The measure of the strain upon the tension rods is the amount they are actually elongated by screwing up. As a combination of wrought and cast-iron, Mr. P. W. Barlow has proposed to cast a bar of wrought-iron in the bottom flange of a girder, and not to make the bottom flange so large. Mr. Locke, Mr. Stephenson, and Mr. C. May, considered that the different rates of expansion of the two metals would be an objection to it. Mr. Brunel objects to the use of cast-iron in long spans, and its combination with wrought-iron, and prefers a framing of wrought-iron and wood.

Bowstring Girder.—Mr. Hawkshaw, Mr. Glynn, Mr. W. H. Barlow, Mr. Locke, Mr. Fox, and Mr. Joseph Cubitt, are agreed in considering the bowstring form of girder, with a bow either of cast-iron or wrought-iron cells and the tension-rods of wrought-iron, as free from any objections urged against other modes of combining wrought and cast-iron. It is considered applicable, under almost all circumstances, as the roadway can be suspended from the bow.

Box or Tubular Girders.—Mr. Fairbairn considers these girders the best for large spans, and from some experiments he made, considers them capable of resisting not only dead weight but also impact. Mr. Stephenson states that they are cheaper and more elastic than other forms for spans of more than 40 feet, and he recommends that the top should be made of cast-iron to resist compression. Mr. Glynn and Mr. Locke mention that they have been used for steam-engines for some time, and consider the plan sound. Mr. Brunel looks upon the introduction of wrought-iron into the construction of girders as the most important step that has been taken for some time in engineering; and he considers that, with ordinary care, and with the improvements which have been introduced in the mode of riveting, the joints made by riveting may be as permanent, and in every respect equal to the other parts of the structure, and he does not consider oxidation or vibration can affect them. With respect to riveting, Mr. Brunel considers that two plates could be riveted together so as to ensure their not breaking in any part contiguous to the rivets or joints, because the rivets should not act as pins or bolts, but as clamps, which by pressing the plates together, produce an enormous friction. Mr. Clarke, however, who has made a good many experiments on the subject, does not appear to have obtained so close an union of the plate, as he states that they generally broke at the riveting. Mr. Hawkshaw has adopted wrought-iron girders for large spans, because he considers the use of wrought-iron more advisable than cast-iron for large spans: the box form is adopted to produce lateral stiffness. Mr. Fox and Mr. Rastrick consider that a large structure, like the Menai Bridge, must be subject to sudden compression and extension from the changes of temperature.

Suspension Bridges.—Mr. Stephenson does not consider suspension bridges applicable to railways except to very small extent; and he states that he has been informed that an engine and train passing over one at Stockton (which has since been replaced by a girder bridge), pushed the bridge like a wave in front of it. Mr. Brunel states that, under very peculiar circumstances, he once proposed a suspension bridge himself. Mr. Brunel considers that the lattice bridge is advantageous only under circumstances which would prevent materials of more than a certain length being procured. Mr. Stephenson objects that the compression cannot be carried through them, and that the base through which the strain has to be carried is not sufficiently broad. It is stated, however, that Sir J. M'Neill has remedied the want of power to resist compression by introducing a cast-iron top.

Best form for Bridges independently of Expense.—Mr. Rastrick, Mr. Hawkshaw, Mr. Fox, Mr. P. W. Barlow, Mr. Glynn, Mr. Locke, Mr. Brunel, and Mr. Cubitt, agree in considering that the best form for iron bridges of large span is that of a cast-iron arch. Mr. Grissell states that he considers a well-made straight girder equally to be depended upon, but admits that the arch is the strongest form: and Mr. Fairbairn says that for spans beyond 70 or 80 feet he would prefer wrought-iron tubular girders. Mr. Stephenson would use narrow wrought-iron girders.

Action on Skew Bridges.—It does not appear that the deflection of girders is sufficient to cause oscillation in engines passing over skew bridges, by causing one side to be deflected to the full amount before the other. But Mr. Stephenson mentions that when the road has been in bad order, one wheel being on the solid angle of the brickwork, while the other was on the soft ballast, has caused considerable oscillation.

Effect of Impact and Vibration.—It is not admitted that the vibration caused by a railway train on bridges would injure the bolts or rivets of compound girders, if well-made and strong in the first instance. Mr. Grissell gives them a large amount of surplus strength, as he thinks that when no greater strength of iron is put than is absolutely necessary, every jar must tend to loosen the joints, and he considers that vibration has much more effect on wrought iron than on cast iron. Mr. Fox states that he would not depend on a cast-iron girder of separate pieces bolted together without strengthening it with a wrought-iron tie-bar, but the use of wooden sleepers interposes a cushion which does away with the vibration. Mr. W. H. Barlow mentions that with light engines he found felt very useful in diminishing vibration, but that with the heavy weights now in use on the Midland line any interposing medium is crushed out. Mr. Stephenson attaches no great importance to vibration, and has laid iron girders on brick without interposing medium; and the fact of old cast-iron mill-work having run for so long a time without breaking is cited by Mr. Hawkshaw, as an instance of the apparently small effect of vibration. Mr. W. H. Barlow considers that the irregularities which exist on the road from uneven joints, &c. in the rails is a greater cause of danger than vibration, and he mentions that to experiment on the impact he caused the rails to be whitewashed for a mile before the passage of a fast train of 12 carriages, and that the small imperfections in the joints caused spaces adjoining them of 5 inches in length to be left untouched by any of the wheels in the train.

Change of Internal Structure in Iron.—Mr. Rastrick mentions that at the Pont-y-Pool Iron Works a bar of wrought iron suspended, and continually struck by a hammer at the bottom, dropped in two after a length of time, but he knows of no instance of a change of structure on railways. Mr. Hawkshaw, though he has observed crystallization in broken rails and axles, has not traced it directly to vibration: he thinks mill-gearing and shafts would furnish good examples, though when they break the various circumstances under which the fractures have taken place should be observed. Mr. Grissell has observed that the vibration to which crane chains are exposed changes the iron from very beautiful malleable iron to the crystalline appearance of cast iron. He does not consider that cast iron is subject to the alteration of structure. Mr. Fox considers that vibration does produce a change in the internal structure of wrought iron, and instances that if the thread of a screw be cut in a wrought-iron bar, and that the bar be broken across the tapped part, the fracture there will be found more crystalline than at the other part: he mentions the frequency with which shafts and mill-gearing break, and states that cold-hammering the axles to give them a high polish changes their internal structure; but instead of remedying the injury by annealing, he recommends that they should be finished at a high temperature. Mr. Grissell mentions that chains of cranes often break with a crystalline fracture, which he attributes to a change in the internal structure, but he does not consider the same effect is produced in cast iron. Mr. Fairbairn states, that repeatedly making a wrought-iron bar red-hot, and plunging it into cold water, renders it crystalline, and that the fibrous texture may be restored by annealing; he considers that percussion renders the fibres more liable to break off short, but that without it is sufficient to cause a considerable increase of temperature, it does not produce any real internal change. Mr. Glynn considers that the structure both of wrought and cast iron is altered by a succession of blows, the wrought to a crystalline structure, the cast to larger crystals; he has observed this appearance particularly in axles, mill-shafts, toothed wheels, crowbars, and crane chains, the latter even when specially made of strong fibrous iron require to be annealed after about three years; the axles of tenders to which breaks have been applied he mentions as particularly subject to this change. He attributes the alteration to galvanic action, induced by the alloys from which iron is never entirely free, and considers that the action is increased by blows. He also mentions that brass wire, of copper and zinc, originally tough and fibrous, continually breaks off short with a crystalline fracture radiating in the form of a star, showing a change in the structure such as would have taken place if the metal had been melted and had crystallized in cooling; this effect is more rapidly produced in an atmosphere containing sulphuric acid. Mr. W. H. Barlow mentions having caused a piece of fibrous iron to be hammered for a long time by a blacksmith, and that he found the iron changed from a fibrous to a crystalline structure; but as axles do not undergo the same sort of hammering, he does not know whether the same effect takes place in them. Mr. Stephenson considers the fact of an alteration of structure as

highly improbable, and cites the connecting rod of an engine having vibrated 25,000,000 times, and yet being perfectly fibrous. In the cases of axles the iron may not have been fibrous in the first instance, for though when a piece of iron is rolled from 1 foot in length to 20 feet it necessarily becomes fibrous, it does not necessarily become so when rolled from 1 foot in length to 6 feet. He says that in all the cases of change of structure which he has heard of there has always been some important link wanting. Mr. Locke considers that concussion would alter the structure of iron, but would not offer an opinion as to whether the fracture of axles arose from that cause; he mentions that a great many axles broke when the crank axles were in use, but that since straight axles have been adopted fewer breakages have occured. Mr. Brunel doubts the change of internal structure, and thinks the various appearances of different fractures result as much from the mode in which the iron has been broken as in any change in structure, and that change of temperature will also produce a variation in the fracture; that iron in a cold state shows a more crystalline fracture than the same iron warmed a little, and that wrought iron does not actually become crystalline and fibrous, but breaks either fibrous or crystalline according to the combination of circumstances under which it is broken, but with the combination required he is not acquainted; he cites the stratification and planes of cleavage of rocks, which may be broken with different fractures according to the mode of applying the blow. Mr. Brunel exhibited various specimens broken, some with a fibrous fracture by means of a slow heavy blow, and some with a crystalline fracture by means of a sharp short blow. Mr. Charles May cites the beam of a steam engine as an instance of continued vibration not affecting iron, and mentions as an instance in favour of the change the fact that a gun used in his works to break pig iron across, at last dropped in two as if it had been cut.

Greatest Weights on Railways.—Mr. Hawkshaw states that locomotive engines are the greatest weights which can come on railways, and reckon $1\frac{3}{4}$ tons per foot linear as the greatest weight for a single line of way. Mr. Fox, Mr. Fairbairn, and Mr. Brunel mention $1\frac{1}{2}$ tons. Mr. W. H. Barlow states that on the Midland there are engines on four wheels weighing 32 tons exclusive of the tender, but that that weight is too great for the permanent way, and that the rails are crushed and flattened by it. Mr. Stephenson and Mr. Locke state, 1 ton per foot linear as the greatest weight which comes on a single line of rail.

Analysis of the Evidence given by the Witnesses examined.

John Urpeth Rastrick, Esq., Civil Engineer.—Has experimented on Staffordshire and Shropshire iron. Prefers forge iron for large castings. With pure mine hot-blast iron is equal in strength to cold blast, but the hot blast enables cinder to be used, which deteriorates the quality. The temperature of the blast alters the quantity but not the quality of the metal produced, about 500° or 600° is preferred. The only guarantee against bad iron is to contract for a particular quality. There is no mode of detecting the difference between two kinds of iron. A mixture of the Penistone ore from Shropshire with the Staffordshire ironstones improved the quality of iron. For strong castings a mixture of pig iron is preferable to mixing the ores; a good mixture is formed from Low Moor iron, Old Park iron, and Colebrooke Dale iron. Cast the bridge at Chepstow. Allows a ton as the breaking weight of a bar 1 inch square and 1 foot between the bearings. Proves a beam to 1-3rd of the breaking weight, but never trusts it to carry more than 1-6th. Iron girders may be cast of almost any length provided they have strength in proportion; made beams for the British Museum 41 feet long in 1824 or 1825, they had open work in the web, and were 3 feet or 3 ft. 6 in. deep; they were proved by laying on 15 or 20 tons of actual weight, and struck with a heavy hammer of 14 or 20 pounds weight. In simple girders, if the height is too confined, the strength required must be given by thickness. A girder will bear the same weight on the bottom flange as on the top. The torsion caused by placing the weight on the bottom flange is very trifling, and cannot take place without a greater amount of deflection in the bearer than should be allowed. Puts on brackets to unite the flange to the girder. The strength of the joists supporting the roadway should be sufficient to prevent them pushing out the flanges. A flange never breaks off. As long as a weight on a girder is not sufficient to injure the elasticity no matter how long it remains. A beam taken out of a mould while hot will break by its own weight. Cast iron is more fragile in winter than in summer. In the Chepstow Bridge of 112 feet span, versed sine 8 feet, the difference of temperature between summer and winter altered the position of the crown of the arch by 2 inches. Bridges requiring a flat soffit are best supported by a bow above the roadway. No combination of wrought or cast iron is equal to a solid casting, the two metals hamper each other. An arch is the best form for a bridge of cast iron. Vibration and impact will not injure the joints and rivets of compound girders if they are strong enough. Railway girders should be so strong that the deflection should be immaterial. At the Pont-y-pool Iron Works a bar of wrought iron 1 inch square was hung up by one end, and struck at the bottom by a small hammer continually for 12 months until the bar dropped in two. The vibration upon a railway bridge is too small to affect it. Doubts whether the fractures of railway axles can be attributed to vibration. If in a railway bridge no permanent deflection has taken place after it has been in use for 12 or 16 months, considers it has not been affected by the running of the train. Has not observed that fish-bolted rails break from becoming crystallized. In proving a girder allows a deflection of $\frac{1}{700}$ of the length. Considers a rapidly passing weight will cause less deflection than a stationary weight. Prefers cast iron in all cases to wrought iron. In a span of 100 to 200 feet an arch is best; if the height does not admit of it under the roadway it should be placed above. The difficulty of transport is the only limit to the length of castings.

John Hawkshaw, Esq., Civil Engineer.—Low Moor iron is the best for girder bridges, good grey Staffordshire the next best. 1-3rd of No. 1 and 2-3rds of No 2 of the best Staffordshire or South Wales iron is a good mixture for large castings. Hot-blast iron is not so strong as cold-blast iron. The only guarantee against the use of hot-blast iron is the character of the founder. The strength of a girder should be seven times the load, and would test it to at least double the load. The spans for simple cast-iron girders might be increased beyond those in use. Would not hesitate to make a simple cast-iron girder of 100 feet span. In designing a simple cast-iron girder obtains the form for the requisite strength by Mr. Hodgkinson's formula, and trebles the area of the top flange to get lateral stability, thus making the top flange half the area of the bottom. In testing beams it is desirable to give vibration by blows while the pressure is on, or if actual weight is applied, to throw the weights into the scale. A girder cannot bear so much weight on one of the bottom flanges as if applied at top. The weight so applied produces a torsion. By increasing the top flange and adding brackets, the torsion is diminished. It would be nearer a practical result to test a beam in the way in which the weight will be applied. The objection to contrivances for throwing the weight in the centre plane of the girder is that by departing from the simple form the liability to unsoundness from the casting is increased. It is possible that weak girders loaded with a permanent weight might increase in deflection after a length of time. The deflection of a girder should be almost imperceptible. The Knottingly Canal Bridge of 89 feet span deflected half an inch with an engine of 22 tons going at 50 miles per hour; the bridge is too weak. Prefers not using compound girders, it is however possible to make them strong and safe. Prefers plain girders with the top flange increased to prevent lateral twisting. It would be useful to ascertain the strength of beams under loads applied as in practice. For spans of 100 or 200 feet which must be crossed with a level soffit a truss like that for a roof is preferable, or a bowstring bridge. Joints and rivets will not suffer from vibration if made originally strong. Where there is impact or vibration there should be large surplus strength, a breaking strength of seven times the load. Has seen numberless cases of broken axles and broken rails, when frequently crystallization existed, but cannot say whether it is attributable to a succession of blows. Experiments on the subject are desirable. Mill-gearing affords examples already made; the cast iron is there subjected to blows and vibration, and the machinery goes on running for years. The use of cast iron in mill-gearing gives confidence in its application to other purposes; by inquiring into the wear and tear of mill-gearing, the length of time that iron will bear shocks might be ascertained. The irregularity in the surface of the rails would cause a weight moving with velocity to deflect a beam more than a similar stationary weight. No practical velocity would be such as not to give time for deflection. Ice does not afford a parallel case; ice has a better surface, and time must be allowed for the displacement of the water. Is erecting two bridges with wrought-iron tubular girders. Wrought iron gives more warning than cast iron. The load on railway bridges may be taken at $1\frac{3}{4}$ tons per linear foot. The heaviest load is a locomotive engine: there is a rule on all railways prohibiting trucks being loaded beyond a certain point. Locomotives weigh about 22 tons, and the tenders 10 or 12 tons. The weight on a bridge covered with locomotive engines, including the roadway would be 2 tons per linear foot. It is desirable to ascertain the real facts with regard to the trustworthiness of cast iron. The conditions under which cast iron is placed in railway structures is similar to that in mill-gearing, and the quantity of cast iron shafting and length of time it has been in use might be ascertained. In making a wrought iron bridge of 100 feet span; it appears easier to construct one of that span of malleable than of cast iron. The cost determined the adoption of wrought iron; objects to the combination of wrought and cast iron except in bowstring bridges. The wrought iron girders are made double, to obtain lateral stiffness. Without reference to expense, an arch is the best form for cast iron. The level soffit is adopted from necessity. For the strength of wrought iron girders, Mr. Hodgkinson's formula for cast iron was used, adopting 70 as a coefficient instead of 26, and taking care to make the upper flange strong enough; has not had enough to do with that form of girder to be certain of the precise proportions.

Charles Fox, Esq., Civil Engineer.—The mixtures to be preferred for particular works depend upon the locality, as the cost must be considered; would use in the Midland Counties iron from Staffordshire and Shropshire, on the sea coast Welch and Scotch. Two-thirds Blaenavon (cold blast Welch), and one-third of Scotch in equal proportions from the Blackband and from the Red Hematite, is a very good mixture. Is convinced that metal made by the hot blast would be as good as from cold blast if the mine were properly treated; but the custom in Scotland has been to care for quantity not for quality. The only guarantee against inferior metal is to contract that girders shall not break with less than a specified weight, and to cast one more than is required, and select any one for trial, and if

it fails reject the whole. In girders not subjected to vibration, considers that the greatest load should not exceed one-third of the breaking weight; in girders for railway bridges, one-fourth. Proves girders to double the greatest load. For girders of new forms applies the proof by dead weight; but in known forms, uses the hydraulic press as being more convenient, observing the amount of deflection. Considers the objection to the hydraulic press obviated by the use of cylindrical instead of conical valves. The load on one of the bottom flanges is not objectionable provided the girder does not cant. Tests girders sometimes by a weight applied to one of the bottom flanges. Considers a span of about 50 feet as the limit for simple cast iron girders. For girders to support a quiescent load would make the section of the top flange one-sixth that of the bottom. In a railway bridge, where the top table would not be supported laterally, would make the area of the top table one-fourth that of the bottom. In a railway bridge, where the top table is supported laterally, makes the area of the top flange one-fifth that of the bottom. The top flange of a girder being subject to compression may be compared to a column; and if bent, its liability to break will be increased. If circumstances required, would make a girder of more than 60 feet long in one piece; roving bridges over the New Birmingham Canal are 80 feet long, cast in one piece. In well constructed bridges the deflection of the platform should not cause any injury. Considers the smallest weight applied impairs the elasticity of a beam, and that a girder exposed to change of temperature and vibration will swag, and that this effect will go on increasing; but he considers that the only diminution of strength from this is due to the diminution of the sectional area of the bottom table; but that in cases where a beam is not subject to change of temperature, it would retain its original position. Instances some girders 6 feet long for supporting hoods to smiths' forges, which are warmed by day and allowed to cool at night; they swag nearly 3 inches in the centre. Considers that in the alteration in the arrangement of the particles of iron caused by a change of temperature the weight takes advantage of the change. Does not consider that removing and replacing a weight on a beam continually would have quite the same effect; mentions that anchors when tested take a week to regain their original position; considers alteration of temperature more likely to produce swagging than vibration. Thinks that railway girders will gradually swag and must be exchanged, and that few which have been ten years in use have not swagged, but that their strength is only impaired to the extent mentioned above; the greater the inertia of the bridge the longer would the action be delayed. Considers the mode of supporting the roadway on one side of the girder to be wrong. The deflection of a girder should not be considered with reference to the span. For large spans, prefers cast iron on the principle of compression. Would make straight girders for large spans of several castings bolted together with wrought iron tension rods fixed horizontally along the bottom flange, and put considerable initial strain upon the wrought iron bars, that the cast iron may come into operation when the wrought iron is under a considerable degree of tension, so that the ultimate effect from the two may be obtained. The expansion produced by changes of temperature being only a differential quantity, would be small in a length of 100 feet; and the wrought iron being more elastic than cast iron, should bear it. The bow string girder, with a bow of cast and a string of wrought iron, would be cheap and safe. A bridge for crossing the Arno is being made of straight girders on the above mentioned principle; the wrought iron bars are under a tensile power of 6 tons per square inch. In process of time the wrought iron would stretch; wrought iron would stretch $\frac{1}{10}$th inch in 10 feet, with a weight of 10 tons. Would not let rails rest on the top of a wrought iron riveted girder without a piece of wood between. Girders made of separate castings should, in addition to bolts, have a wrought iron tie bar. Soft timber between the rails and girders will prevent danger from vibration. Considers alteration of temperature as likely to subject wrought iron girders to a great deal of undue compression and extension. Thinks experiments on impact and vibration desirable. Believes that wrought iron is rendered crystalline by a succession of slight blows at a low temperature, and has observed that the older axles are, the more crystalline they are; also remarks, that if the thread of a screw be cut on a bar of fibrous iron, the tapped part will break with a more crystalline fracture than the other. Shafts in mill work break and exhibit a crystalline structure. Thinks cold hammering injurious to axles from tending to make them crystalline, and also from producing a strain like that produced by straightening castings by hammering. Would prefer their being finished at a high temperature to being annealed. Cold hammered axles may be detected by their appearance. Thinks experiments on long continued deflection are very desirable. In estimating the strength of a girder, adopts as the greatest weight $1\frac{1}{4}$ tons per foot per single line of way; that is $\frac{1}{4}$-ton per foot for weight of platform and 1 ton per foot for weight of train; for two girders of 40 feet span, would take the weight at 60 tons distributed, equal to 30 tons in the centre. Would calculate the breaking weight of each girder at 60 tons in the centre, and prove them to 30 tons. Considers that with a carefully laid road the deflection due to rapidly moving weights is less than that due to such weights at rest, from the shorter time allowed to overcome the *inertia* of the bridge. There has been a great want of fixed principles in the construction of railway bridges: no general principle has been laid down; whilst one engineer is satisfied with one amount of proof, another adopts six times as much. In making contracts for railway chairs, stipulates that the mixture he uses when cast into a bar of a certain form shall break with a specified weight. Is inclined to think the castings from the air furnace better than those from the cupola, but the difference is very minute.

Henry Grissell, Esq., Iron-founder and Machinist.—Amongst other large works, is at present constructing a built girder bridge for a span of 11 feet; it is 12 feet high, and weighs 100 tons; it has been proved to 188 tons distributed over it. Has not studied the chemical constitution of iron. Prefers a mixture of iron for castings. The mixture depends on the state of the markets; and from old iron being so plentiful in London, pig-iron is not considered so much as in the country. Mixes Scotch iron, old iron, cold-blast Welch iron, the proportions being dependent on the appearance of the fractures; for cylinders a larger proportion of cold-blast iron is used than for girders. Considers London castings 15 per cent stronger than country ones, from the use of old iron. Hot-blast iron when mixed is as good as cold-blast, but alone it is not to be depended on. The proportions for mixtures are so dependent on the qualities of iron, that he is guided by the appearance of the fractures in determining them. Considers he could mix iron so as to make a casting bear any weight in reason. Could not tell hot-blast from cold-blast iron from the fracture. The proportion of stress to strength varies with the section of the girder and the strains to which it is subjected; generally considers the load should be one-third the breaking weight for railway bridges. Handed in the rule he adopts in calculating the strength of girders. Has made simple and compound girders. Would make a girder in one casting 50 or 60 feet. Considers a level top flange a waste of metal. In designing a girder, judges by the eye of the probable strains it would be subject to, and then calculates the strength, and alters the form so as to obtain the greatest strength with the least quantity of metal. Adopts the double T section, the bottom flange being largest. Girders may be proved by a lever or an hydraulic press; the latter is what he usually adopts, and it is as certain as the lever when correctly made. Does not think a girder will bear the same weight if applied only on one flange as if applied to both equally. Proves girders to find out whether the casting is sound, and so applies the proof to the top. Has never noticed that length of time or change of temperature makes beams swag. For compound girders prefers the built girder. Considers half an inch deflection may be allowed in every 20 feet of length; can regulate the deflection by the mixture of iron he uses; would not consider a beam injured by a deflection of $\frac{1}{8}$ inch in 20 feet, if it returned to its original position. For large spans when not tied by expense or height, would generally prefer a built girder. But thinks that an arch is a stronger form than a straight girder, but more expensive. Would guarantee a straight girder with top and bottom flange to bear any amount of pressure. Would not hesitate to use one for a span of 200 feet; thinks it would bear any weight that could come on. Does not think impact and vibration would affect large bolts and rivets, but that where no more than just the necessary strength is put in, every jar would tend to loosen them. Thinks vibration dangerous to wrought-iron; vibration takes much more effect on wrought than on cast-iron. Has observed in crane chains an alteration in the structure of the iron, after a few years' use; instead of its breaking with a black tensile appearance, it breaks short and white like cast-iron; it is changed from beautiful malleable iron to the appearance of very good cast-iron. Cold hammering will also produce this effect on cast-iron, but it can be restored very nearly to its original texture by annealing. Feels convinced wrought-iron girders will become altered to a crystalline texture by vibration. Knows no case of cast-iron becoming altered, or breaking from vibration alone. Has not given his attention to axles. Has made numerous experiments on iron of all sorts and mixtures. Considers that if the form of a girder be given him, he could mix the iron for making it to such a degree of nicety, that he could guarantee any amount of deflection, and carry any load required in moderation. Attaches the greatest value to old iron, but not to differences in pig-iron; considers all Scotch iron to be much of the same quality, except one or two sorts, which are very superior. The metal for mixtures must be selected with great judgment. Does not consider it necessary to try the relative strengths of the different sorts of metal before mixing, but judges of the proportions by the fracture. A good mixture would be one-third hot-blast iron, one-third old iron, one-third Blaenavon Welch iron, but he does not confine himself to one particular mixture.

Peter William Barlow, Esq., Civil Engineer.—Has been employed chiefly latterly on the South-Eastern Railway. Has not observed much difference in the strength of castings. Has always made the breaking weight of girders six times the greatest load for railway bridges. For other works four times would be sufficient. Proves girders to one-third of the breaking weight, or double the greatest load. Prefers proving them with actual weight, and giving some vibration to the beam by putting on the weight. Girders will not bear the same weight when resting on the bottom flange as if applied at top. Has adopted another form of girder, the object being to make the bridge one complete plate. Considers 40 feet as the limit for such a bridge. Has made one over a railway at Tonbridge wells. Finds that the deflections are less than he calculated, from the assistance one part affords to another. Has not observed any injury from the bending of the joists which carry the roadway between two girders. Has not noticed any increase of deflection from a permanent load or from

changes of temperature. Allows $\frac{1}{600}$th of the span for the deflection of a girder. The deflection of the Godstone Bridge is $\frac{1}{700}$th of the span, or $\frac{5}{8}$ths of an inch. Proposes 40 feet as the limit for simple cast-iron girders. Used a level and levelling staff for obtaining the deflections of the Godstone Bridge. Considers the girders rest so firmly on their beds, that the deflection observed is not due to any yielding in that respect. Depends on Mr. Hodgkinson's rules for the form of construction for girders. Has made no experiments on the amount of torsion caused by supporting the roadway on the bottom flange of a girder. Considers a girder of separate castings bolted together is a good mode of construction beyond spans of 40 feet. Would not use that method for bridges of 100 feet span. Would limit girders cast in one piece to 40 feet span. Does not consider suspension rods a good mode of combining wrought and cast-iron. Would lay a wrought-iron rod along the bottom flange. Assistance given to the extended part of a beam is more effective than when given to the compressed part. To avoid a large mass of cast-iron, would lay a wrought-iron rod along the bottom flange. Does not consider that the different rates of expansion would prevent the wrought-iron coming into play. When the bridge gets much load it must come into play. Prefers an arch of cast-iron where expense or height is not a matter of consideration. Is making one over the Surrey Canal of three pieces bolted together. Does not consider the vibration on a railway bridge sufficient to disturb the screws. Does not consider that there is much difference of effect between engines going fast or going slowly. Does not think vibration so important as is imagined. Fancied he observed an increase of deflection from engines going fast; there was a great deal of horizontal jar. Which he attributes to blows given by the engine on the rails. Some may be due to the torsion created by the weight being on one of the bottom flanges. Has not observed any change produced in the internal structure of iron from repeated blows at a low temperature. Thinks the subject an important one, and that experiments could be made best by breaking beams which had been long in use. Or testing girders whose previous test had been recorded. Engines and tenders are being made, weighing together 32 tons. Engines for inclines weigh as much as 30 tons without a tender. In estimating the greatest load for a railway bridge, considers it covered with a train, or a train composed of engines. Considers the Commissioners might make some useful experiments on the Godstone Bridge. Has paid attention to wrought-iron girders. It is desirable in a girder to concentrate the power of resistance as near the top as possible, and the power of extension as near the bottom as possible, which can be accomplished in a cast-iron girder; but in wrought-iron tube girders the bottom web, which does most work, is a very small proportion of the whole section. Prefers wrought-iron, or wrought-iron combined with cast-iron, to resist compression, to cast-iron alone. Considers solid-sided wrought-iron girders an imperfect mode of construction. Thinks the top of tube girders should be of cast-iron. For a large span, considers wrought-iron safest. On account of the uncertainty of cast-iron would make a cast-iron girder 50 per cent. stronger than a wrought iron one. The relative expense would be about half.

William Fairbairn, Esq., Civil Engineer.—In early life was a mechanical engineer. Has been employed in engineering works of various descriptions. Thinks Welch cold-blast iron, Blaina, for instance, best for girder bridges. Considers most British irons improved by mixture. A good mixture is two-thirds strong Welch, No. 2, the remainder Scotch or Staffordshire, No. 2, with a little old iron. The same mixture is used in girders for railway bridges and girders to support dead pressure only. Thinks Mr. Morries Stirling's patent for mixing wrought iron with cast iron gives indications of very superior strength, and states the results of experiments upon it; also cites experiments by Mr. Lillie, of Manchester, on the mixture of wrought and cast iron, which proved that the mixture was one-third stronger than common cast iron, and one-eighth stronger than wrought iron to resist transverse pressure. Considers the following mixture of cast iron the best, viz.:—

Lowmoor, No. 3	30 per cent.
Blaina, No. 2	25 per cent.
Shropshire or Derbyshire, No. 3 . . .	25 per cent.
Good old scrap	20 per cent.
	100

This mixture can rarely be obtained on account of the price of Lowmoor, and founders cannot be depended upon for the exact proportions. Practically he doubts any mixture unless the parties interested were present to witness the selection of the iron, and to see it put in the furnace. Scotch and Staffordshire iron are good for light castings. Good castings depend on the care of the furnace man, the temperature of the furnace, and the heat at which the metal is run into the mould. Recommends the anthracite iron where rigidity and strength is required. The strongest iron should be put in railway bridges. Considers that the hot blast does not improve the quality of Welch and English irons; but that its application in the Scotch furnaces to the reduction of the black band is an improvement. Scotch hot blast mixes well with Welch irons. The effects of the hot blast vary with the quality of the fuel and ore, and much depends on the quantity of sulphur present in the coal and coke. The Lowmoor ores were injured by the application of the hot blast. Fuel is an important element in the manufacture of iron, the nearer it approaches pure carbon the better. In the Scotch black band and similar ores the hot blast will bring more iron out of the same mine than the cold blast. The hot blast enables the manufacturer to work up not only poorer ores but cinder heaps, into apparently fine granulated iron. The use of the hot blast at first led to the introduction into the market of a very inferior description of iron. Considers the Scotch iron weaker and more fluid than most English irons; it is equal to Staffordshire, but weaker than Welch and Yorkshire. Scotch iron is an exceedingly fluid and fine-working iron, and well suited to machinery; it runs well into the mould, and brings out the castings with the edges sharp. Does not think the most experienced metallurgist could tell the difference between hot blast and cold blast iron from the appearance. Considers that hot blast presents greater uniformity than cold blast in its granulated appearance, and indicates a more perfect process of crystallisation, probably arising from the greater heat of the furnace. In cast iron girders, would make the breaking weight four times the greatest load. In structures exposed to shocks or vibratory motion would adopt five times or six times. It is safer to adopt a light load, so as to make allowance for casual strains which cannot be computed. Never proves a girder to more than half the breaking weight, generally one-third; disapproves of testing a girder much beyond the permanent load, the object being to ascertain its soundness and elasticity; a further test tends to permanent injury. In testing girders, carefully inspects the outward appearance, and then hangs weight from the centre, and observes the deflection and permanent set. Does not consider that a permanent set given to beams in the early stages of loading injures the strength. Thinks that within certain limits the form of a beam may be distorted without its strength being injured. Considers that to support the load on one side of the bottom flange is wrong in principle, and to a certain extent injurious in practice; but the method has many conveniences: to meet the requirements of structures, self-evident principles must in practice be sometimes abandoned. When the load is supported on the bottom flange, the bearing should be brought as close as possible to the central web, by casting a fillet or shelf to carry the cross-beams: bolt holes should be made as near the neutral axis as possible, or when required for bolting wooden bearers to the bottom flange, projections on the bottom flange should be cast to receive them; bolting the roadway to the girders resists, in a great measure, any lateral strain on the girders; but the lateral strain is best resisted by broad top and bottom flanges. Considers bolt holes and other perforations in cast iron girders very objectionable, and they should in no case be made, even through the neutral axis, without thickening the adjacent part to compensate for the part taken out. These objections arise from considering the complexity of such a girder and the additional material required to make it equally strong as if plain. Is an advocate for simplicity of construction in everything, and would only allow distortion of form when inevitable. Would prefer supporting the cross bearers on the top flange or suspending them from the bottom flange by hook bolts. Supporting the road on one side of the bottom flange is wrong in principle, but convenient. If the top flange be broad and rigid, that mode of construction is less objectionable. It would be advantageous to seek for a new form of beam; a narrow top flange, though well proportioned for vertical pressure, is weak to resist lateral strain. The practice of supporting the roadway on the bottom flange is simple, cheap, and convenient, and will not easily be abandoned. Recommends a new form of girder to be sought for, to give the girder sufficient stiffness. Has himself always increased the top flange to resist the lateral strain. In a large span with girders having small top flanges, the lateral deflection, if not resisted by a firm connection of the cross beams to the girders, might cause an outward pressure dangerous to the structure. As girders are generally tested to ascertain their soundness, it is usual to apply the test to the top flange, but it would be of great value to test them as they are to be used. The test is usually applied to ascertain the soundness of the casting, the strength being computed at three or four times the load. The joists which support the roadway when carried on the bottom flange, tend to cause by their deflection a lateral pressure on the girder. This effect takes place to some extent in wooden and Sandwich beams; from experiments it appears that this latter description of cross beam is weak, and its elasticity so imperfect as to render it inadmissible for supporting great weights. The Sandwich beam is objectionable and expensive. Is of opinion that a beam loaded with a given weight, even approaching its ultimate powers of resistance, would support the load *ad infinitum* if not disturbed or exposed to changes of temperature; although time is an element in the change which takes place in every material, any increase of deflection in a loaded girder may be traced to atmospheric action, vibration, change of load, and temperature: remove these disturbing causes and the deflection will remain fixed. Cast iron of average quality loses strength when heated beyond a mean temperature of 220°, becoming more ductile and less rigid to resist an uniform strain, and becomes insecure at the freezing point or under 32° of Fahrenheit. In girders of 40 feet span $\frac{7}{8}$-inch is the maximum allowable deflection, that is, ·02 inches per linear foot; ·005 inches is preferable. Adopts Mr. Hodgkinson's form of girder modified in the top flange to ensure uniformity in the casting. Considers 40 feet to be the greatest allowable length between the supports for simple cast iron girders. Knows an instance of a girder 70 feet long, cast in one piece in Holland. Never heard of a girder breaking by its own weight; a properly proportioned girder could not do so. For spans beyond the limit of simple cast iron girders which must be passed with a level soffit to the extent of 100 or 200

feet, Recommends the wrought iron tubular or box girder. Being a strong advocate for simplicity in mechanical structures, he would not recommend compound girders where they can be dispensed with. Approves of wrought iron tension rods to girders only in cases of necessity, and where the top flange is enlarged, but prefers girders all of one material, even if formed in parts. Would rather give strength to a cast iron girder than assist it by a wrought iron truss; the two materials are so widely different in character that it is safer to keep them separate. By screwing up the tension rods a strain is thrown either on the girder or on the tension rods themselves; an ignorant person might do injury without being aware of it. When not limited by expense or levels, would prefer for narrow spans a simple girder; for moderately wide spans, the arch; for spans exceeding 70 or 80 feet, the wrought iron girder. Thinks that no vibration to which railway bridges are subject can injure the joints or rivets, unless the work is shamefully executed; nor would impact have any effect on the joints of a well-made cast iron girder. Does not think any effect is produced by the load in skew bridges being alternately nearer one side than the other. It is the opinion of some practical men and philosophers that iron when hammered at a low temperature undergoes a complete change in its internal structure, and that this effect is due to percussion, heat, and magnetism, and time, which is an element in every process of crystallisation. The application and abstraction of heat operates more powerfully than probably any other agency; too much influence is probably attributed to the other-mentioned causes; a bar of the best wrought iron, heated red hot and plunged into cold water, is changed from a fibrous to a crystalline body; heating and cooling will produce this effect in a degree proportioned to the intensity of the heat applied; by annealing the iron its fibrous texture is restored, and sometimes made more tough than before. Thinks magnetism may have some effect; but often where causes are inexplicable we fly to electricity for the solution; heating iron to a high temperature deprives it of its magnetic powers which are restored by cooling. Doubts that vibration changes the fibrous structure to a crystalline one, but thinks that each blow produces injury. Axles of a locomotive engine are subjected to repeated shocks from irregularities in the rails and lateral action in passing curves, from a body weighing 18 or 20 tons, moving at 40 miles per hour. Each percussion tends to bend the axles, and from the injury being continued many thousand times, it is evident that time alone will determine the moment of fracture. If the axles were so rigid as to resist the effect of percussion, no injury could ever take place or crystallisation appear. A bar beat with a small hammer is not altered at all, but the blows of a large hammer produce a change of form which renders it brittle, not probably crystallising it. Is of opinion that a fibrous body cannot be changed to a crystalline one by any mechanical process, except when percussion is carried on to the extent of producing a considerable increase of temperature. Fibres may be shortened by continual bending, and the parts be thus made brittle, but fibres cannot be changed into crystals. These changes apply to all materials subjected to repeated alterations of form. Has not traced the breaking of mill work to the change of internal structure. The shafts usually break eventually from getting out of line. It would be interesting and useful to experiment on the above points. The greatest weights on railways may be reckoned at 1½ tons per foot linear for a single line, or two tons per foot for a double line of rails. Considers that recommendations made by the Commission as to particular forms for bridges would probably not be followed, but that experiments would be very beneficial.

Joseph Glynn, Esq., Civil Engineer.—Was engineer-in-chief to the Butterley Company. Cast iron is always combined with earths, as lime and silica, as well as with carbon; the more pure the iron is the stronger it is. Never saw pure iron. Iron cast from the air furnace of a mottled or of a clear grey fracture, bears the greatest weight. Iron cast from the air furnace is stronger than from the cupola. Doubts the utility of mixing wrought with cast iron for increasing the strength of iron; doubts the complete union of the two. The quality of iron depends, to a certain extent, on the ore, fuel, and flux used; and an experienced person can generally tell what the produce will be. From a reverberatory furnace the required mixture can be invariably produced. The length of time iron remains in the furnace affects the quality. In the air-furnace it is weakened by remaining too long. The best mixture for girders is about one-third of strong crystalline Welch iron with two-thirds of the softer irons of Derbyshire, Yorkshire, or Shropshire. The hot blast of itself produces no effect on iron. It may be used to smelt stubborn intractable materials that would not afford strong iron, and could not be otherwise smelted. In the west of Scotland inferior iron has been produced by means of the hot blast. There is no certain mode of detecting the difference between hot and cold blast iron, but iron of a dark grey colour and very fine in the crystal is generally hot blast. The difference is more marked as iron is harder. Loam castings are stronger than open sand. Casts machinery required to be very strong from the air-furnace in dry sand. A shaft cast in an upright position is stronger than one cast horizontally on account of the impurities floating to the top, and the density being increased. Adopts the H form for the section of girders, the bottom flange being largest. Would not make a simple cast iron girder more than 50 feet long. Where spans have exceeded that, has always used the arched form. Built an arched bridge of 70 feet span over the Aire, at Huddesley; and one of 100 feet span over the Trent on the Midland Counties Railway. Would invariably employ an arch when possible. Would not employ wrought iron as an auxiliary to cast iron in point of strength. Would only employ it for bolts; on a large scale the workmanship cannot be so accurate that each will bear its share of the stress. For spans beyond 50 feet, would give the girder as much depth as possible, and join the pieces by bolts and dowels. Would not have a wrought iron truss. When the workmanship is good, does not consider the vibration and impact can affect the bolts and rivets. Believes that the internal structure of iron becomes altered by being submitted to a succession of slight blows at a low temperature. Has seen many axles broken which presented a coarse crystalline fracture. The continual succession of blows induces fracture, and changes the internal structure of fibrous iron to crystalline, the crystals increasing in size as the effect goes on. Crane chains made of fibrous iron break in a few years with a crystalline fracture. Considers the same effect takes place in cast iron. Shafts in mill-work break. And there appears to be a limit as to time in the durability of wheels. The fractures in these cases exhibit an increased size of crystals. Considers that a stationary weight would deflect a beam more than a moving one. Never made large girders of wrought iron plates; the method is adopted for paddle beams of steam-vessels, vibration has not affected those made for steam vessels, nor did the rivets become loose. Considers that the strength of a wrought iron girder is diminished by rivets.

William Henry Barlow, Esq., Civil Engineer.—Is resident engineer to the Midland Railway. Has found so much difficulty in obtaining the quality of iron specified that he now simply specifies the dimensions of the girders and the test to which the iron is to be submitted, leaving the mixture to the founder. Objects to the inferior qualities of cinder iron and hot blast iron generally; though, at times, hot blast iron exhibits good results. Some specimens of hot blast are as strong as cold blast. Hot blast iron seems more liable to abuse in manufacture than cold blast. Is not aware of any mode of telling hot blast iron from cold blast. Specifies that girders should bear a given weight with a given deflection. Would make a girder so that the breaking weight should be four time the greatest load. Considers that safe for weights moving at high velocities. Proves a girder to half the breaking weight. It gives the girder a permanent set, but does not consider that it injures its strength. The proof is proportioned to what the girder has to bear. Tests them by dead pressure by the hydraulic press. Has not tried impact, during the test but thinks it might be desirable when the breaking weight of the girder is nearly approached; but, practically, would give a large amount of surplus strength. Never allows the load to exceed one-fourth of the breaking weight; it is often one-fifth. The pressure being applied in the central plane of the girder. In actual structures the pressure is usually applied to one side of the bottom flange, but does not consider that when the surplus strength is so great and the iron good that it is of importance to apply the test in the same way. A torsion is introduced; it is not, however, so perceptible in short girders. The effect of a great permanent load on girders is not in operation in railways; but girders do not appear to be deteriorated by the frequent passage of a load. The one-fortieth of an inch to a foot is assumed as the amount of deflection that may be allowed in girders, but it is empirical. The short time which a load rests on a railway girder apparently renders the weight of less effect than in warehouse girders which bear a large load for years. Observed once on a timber viaduct that a goods train produced a certain amount of deflection; an express train coming afterwards, though with a lighter engine, seemed to produce a wave through the bridge, and evidently produced a worse effect than the goods train. The point of maximum effect would not be when the load was in the centre of the bridge. And this is probably a reason for allowing girders to deflect less in railway bridges than when exposed to dead pressure only. Has generally adopted Mr. Hodgkinson's form of girder. In spans of 50 feet, whenever the headway allows, prefers and has adopted arched girders, which are supported by abutments, and also act as girders. A skew bridge on that principle is a series of square bridges. The arched girder for the bridge over the canal at Weslock is in two pieces, bolted together in the middle; the rise is one-tenth. There are cases where on account of the headway rectangular openings are required, but they are rare; girders have been used to a greater extent than necessity required, from being in fashion. The length for cast iron girders will be limited by the power of casting them; has not used any longer than 42 feet. The bowstring bridge is the best mode of construction where the spans are too large for simple girders, a cast iron arch with a wrought iron string. In a very large structure the rise of the arch might allow of a pair being tied together at the top. If in combinations of wrought and cast iron, the two metals are bolted side by side, the different rates of expansion might produce a bad result. Has not found that the impact and vibration to which railway bridges are subject has produced any bad effect on the bolts and rivets of bowstring girders. The girders in skew bridges might, if the deflection were excessive, suffer from the load coming on the centre of one girder before it comes on that of the other. Except at high velocities the maximum effect will take place when the load is at the centre. To try the effect of impact of trains, whitewashed the rails for a mile on an incline of 1 in 316, and watched the effect of a fast train of 12 carriages going down it over them; in cases of imperfections at the joints, there were spaces 8 inches in length untouched by any wheels in the train. The rails weighed 75lb. and were on wooden sleepers. Used to use felt as an interposing medium to diminish vibration, which answered for light engines; the present ones are so heavy that any substance is soon crushed out.

Some engines weigh nearly 30 tons; a new one on four wheels weighs 32 tons. Has observed that the internal structure of small pieces of wrought iron becomes altered by blows. Caused a piece of the best and most fibrous wrought iron from the Lowmoor works to be hammered by blacksmiths for 10 minutes, and quite a change in the texture was produced; by continuing the hammering for half-an-hour, it was altered from a fibrous to a granular texture. Axles are not exposed to the same sort of blows as hammering gives; but axles have broken with a crystalline fracture. The very heavy engines lately introduced begin to crush the rails; eight tons on each wheel seems beyond what the rails as now constructed can *carry*. The wheels of the large engine above mentioned are 18 feet apart. It has travelled with two carriages at 78 miles per hour.

Robert Stephenson, Esq., M.P., Civil Engineer.—Mentions that it is well known that the fluidity of Berlin iron is due to the presence of arsenic, and that the Welch and Yorkshire irons are contrasted by the one being hot-short and the other cold-short, which is due to the presence of phosphorus on the one hand and manganese on the other. Used two or three cwt. of the new iron from India; but the workmen did not understand it; it retains its malleable properties to a high temperature, and then loses them very suddenly and becomes fluid. Mr. Morries Stirling's method of introducing wrought iron into cast iron, is a commercial question, unless it gives more flexibility or toughness to the cast iron and makes it approach the quality of wrought iron; for if the additional quantity of common iron required to make up for the difference of strength can be introduced at less expense than his mixture can be procured, he would be beat out of the market. Weight is, however, an important element in steamboats. Prefers a mixture of irons wherever it can be obtained, without having any specific opinion as to which mixture is best. Made several experiments on mixtures at Newcastle; does not think the difference between any irons so great as to make it worth while incurring additional expense; 5, 6, or 7 per cent. is probably the range on one side or the other from the medium of all the irons in this country; when using hot blast iron, alters the constant in Mr. Hodgkinson's formula to make up for any defect in quality. Hot blast iron being very fluid, is better adapted for small articles than cold blast; it appears to approach the Berlin metal. Would use either hot blast or cold blast iron, but prefers a mixture. Though you may specify that the iron be without cinder, you cannot ensure getting it. Has not found much difference between anthracite and other iron. The large castings for the bridge at Newcastle are of anthracite and hot blast from the neighbourhood. Considers that there is very little difference between the strengths of different irons, and that it can always be made up by varying the constant in the formula. Never met with iron varying 15 per cent. from a standard. Is of opinion that, taking the average of irons in this country, there is a great proximity to an uniform standard; irons vary to a small extent on each side of that standard. Though one iron compared with another may give a great difference of strength, a mixture, for which all engineers stipulate, annihilates these variations. Always adopts Mr. Hodgkinson's formula. Adopts the constant he gives, viz. 25 or 26 with a mixture; if compelled to use hot blast iron, would take 20 as the constant, this number being derived from experiments. Has not the same confidence in hot blast as in cold blast iron, rather from opinion than experiments. Understands that the fracture of hot blast is darker and more carbonaceous than cold blast, which should be a dull lead grey. Generally employs six times the working load to be the calculated strength of a girder, and tests it with a weight equal to two trains of locomotives, or two tons per foot in length. Has added to the bridges built on the plan of the Dee Bridge, three castings corresponding to the lower ones, by means of which the line of thrust is raised above the horizontal line. The deflection of a bridge of 90 feet span so altered was 1·98 inches with 56 tons in the centre, equal to two trains of locomotives; it is rather too stiff; considers that a certain amount of flexibility in a cast iron girder is essential to resist the suddenness of the passing weight; it should yield so as not to convert pressure into concussion. Tests large compound girders to one-third the breaking weight, and small simple girders to one-sixth. Tests small girders with the hydraulic press; large girders, with dead weight, suspended from the centre. Iron clamps holding the bottom flange support the platform for the testing weight. The weight is applied in the centre. In bridges it is applied on one side, but the torsion so created is very inconsiderable and may be disregarded. It is not necessary to test girders with weights applied as in practice; the beams that form the platform rest close to the vertical web. When girders have been tested accidentally in that way, has not found any difference; when two girders are tried by the hydraulic press it is by accident only that the pressure is exactly in the vertical plane. Does not consider that alterations take place in iron bridges from length of time or change of temperature; the engine beam of a Cornish engine, with a 90-inch cylinder, receives a shock 9 or 10 times a minute, equal to 56 tons; has known them work for 30 years without the smallest perceptible change. On the Blackwall Railway, 120,000 trains, each of 12 carriages, have passed over girders of 48 or 50 feet span, and when examined four or five months ago, no perceptible change had taken place. These girders were not made to carry locomotives, and they are doing as near their ultimate duty as girders carrying locomotives. With respect to the question of change in the internal structure of wrought iron, knows of no instance where some important link was not wanting to complete the reasoning; that hammering may produce brittleness in iron is probable but not certain; the connecting rod of a steam engine vibrates at ordinary speeds eight times in a second; one just come into the shop from the Norfolk line has run 50,000 miles; the rod has vibrated 25,000,000 of times; yet, apparently, no change can be detected. With respect to axles, has never been able to come to a conclusion whether the axles that broke were fibrous to begin with. The connecting rod being so much smaller, is more likely to be fibrous; a piece of iron rolled from 1 foot to 20 feet is almost necessarily fibrous; but when rolled from 1 foot to 6 feet it is not necessarily so. Does not believe any change takes place in cast iron. Considers $\frac{1}{40}$th of an inch to a foot may be allowed as the deflection for a girder. Considers the deflection from a moving train to be less than that from one at rest. There may be a lateral strain, but is satisfied that the vertical strain is less. Adopts Mr. Hodgkinson's form of girder, with slight variations according to circumstances. Usually puts two girders under one rail with a baulk of timber between for short spans; in some cases it is desirable to have no top flange. With statical pressure adopts 8 to 5 as the proportion of the top to the bottom flange. The difficulties of casting prevent the theoretical proportion being always the best. In large girders has sometimes adopted Mr. Hodgkinson's proportion of five to one. In some cases has made the top and bottom flange equal; although some part of the metal may be thrown away as far as strength is concerned, it is very useful for other purposes. Has made cast iron girders 80 feet long, but now limits them to 40 feet, and then uses wrought iron. For small spans almost invariably uses two girders, with a baulk of wood between, under each rail; it is a convenient way of disposing of the material and getting sound castings, and they are easily handled. They are being used at Penmaen Mawr, where there were 19 spans of 35 feet each. The timber forms a cushion for the rail. In bridges beyond the limits of cast iron girders considers that girders formed of separate castings, with a tension rod along the bottom is as good a form as any; but considers that there is this advantage in having the tension rods at an angle, that you can bring the tension of the wrought iron into play so easily. When such a bridge is wanted on a large scale, the vertical elevation might be divided. When the joints are planed and fitted accurately, such a girder would be as secure as a solid one, as in a large mass the contraction from cooling is liable to be unequal. Has tested compound girders without any bolts and depending on the tension bar, and also without the tension bar but depending on the bolts. The extension of tension bars with 10 tons per square inch is $\frac{1}{1000}$th of the length, and the iron comes back to its original state. The piston rods of Cornish engines go on without being lengthened. Tension rods will not permanently suffer as long as the strain is within the limits of elasticity. With respect to the tension rods in the Dee Bridge which acted at an angle, does not allow the objection that with deflection they might become slackened, but would undertake to break the tension bars by putting on a strain, and that the girders can be cambered by them. Would use wrought iron girders over spans where there was no limit as to expense or levels. Thinks that a bar of wrought iron cast into the bottom flange of a cast iron girder might be too intimate an union on account of the different rates of expansion of the metals; if, however, the proportion of cast iron to wrought was very large, it would not be of so much consequence. It is much the same as bolting a wrought iron bar to the bottom flange of a girder. Does not consider that the vibration and impact to which railway bridges are subject would injure the bolts and rivets. Has observed one or two instances when oscillation was produced on skew bridges when the road has not been in good order close to the bridge, and one wheel came on to a solid angle when the other was on soft ballast; generally now brings the two sides square by means of a wooden baulk. In skew bridges, when oscillation is prevented, both girders are subject to the same vibration. The deflection of a girder would not throw the engine into oscillation; the engine moves at the rate of about 70 feet per second, and there is not time. The deflection of the girder is only a small objection. The approach to the bridge causes the danger. Considers experiments on impact and vibration advisable. An ordinary train weighs about five eighths of a ton per foot in length. Engines are about a ton to a foot in length. Considers wrought iron girders preferable to cast iron for spans exceeding 40 feet, as being more elastic. Found a very marked effect from introducing a cast iron top in the box girder in the Chalk Farm Bridge. Considers a collection of facts would be very valuable, but any legislative enactment, with reference to the construction of bridges which would hamper engineers, would be very objectionable. Attaches very little importance to vibration, and considers it of little consequence for girders to be laid on ordinary walls without interposing medium. Considers suspension bridges very little applicable to railways; indeed, with the prospect of increasing weights, totally inapplicable. Thinks Dredge's principle scarcely applicable with heavy weights. The more ties they have to the platform the better. Has been informed that a train passing over a suspension bridge at Stockton of 300 feet span caused a wave 2 feet high like a carpet. Understands that American engineers have given up lattice bridges entirely; they soon rack themselves to pieces; the timber is cut into slices instead of being in lumps. The thin bars of an iron lattice bridge make it impossible to convey compression through them; it is "wabbly." Sir John M'Neill has remedied the want of power to resist compression by putting a cast iron top. Exhibited drawings of the wrought iron girder for the Chalk Farm Bridge, with a cast iron top to resist compression. The method adopted to strengthen girders on the Dee Bridge plan, and girders with tension rods along the bottom flange for bridges over the River Arno. Also an experi-

metal girder, similar to the Dee Bridge girder, from which it appeared that the tension rods when acting at an angle could camber the girder. Girders are made in separate pieces on account of the difficulty of cooling large masses, and the inconvenience of conveying them. Thinks it would be imprudent to make larger castings than those recommended for girders. Has had failures. Although there is a considerable variation in the strength of iron, there is a remarkable approximation to an average standard. Practically an engineer is not justified in going to any great expense to get a particular quality of iron. A difference of 20 per cent. in samples of iron is not of much consequence when the girders are made to bear six times the load that comes upon them. Does not consider that any injury can arise to a girder from the bending of the joists supporting the platform; in many cases has had the bearing secured close to the central web. Prefers, instead of depending on one girder, having two bolted together, with a baulk of timber between. Prefers a wooden platform to one resting on iron beams; does not apprehend danger from the vibration, but the noise is so unpleasant that some soft medium should always be interposed.

Joseph Locke, Esq., M.P., Civil Engineer.—The strength of iron will depend upon mixtures. Prefers a mixture. The mixture of hot blast iron with cold blast considerably increases the strength. Understands that a mixture of wrought iron with cast adds to its strength. Considers it better to trust to the knowledge and experience of iron founders of high character than to specify for particular mixtures. Has generally made the breaking weight of girders from three to four times the greatest load; but the load is supposed to be dead weight, whereas the shocks in railway bridges may increase it to within half the breaking weight. On railways from the levels the most convenient form of girder must sometimes be adopted in preference to the stiffest. Would not prove a girder with more than double the greatest load. Thinks dead weight a more self evident mode of proving girders, but that the hydraulic press is a very convenient and good mode. Resting the weight on one of the bottom flanges produces torsion to some extent. Thinks it might be desirable in some instances to test the girders with weights applied, as in practice. Has known cases where the test was applied to one flange as in railway practice. Never knew a flange break off a girder. To prevent the girders getting out of the perpendicular, makes the baulks supporting the rails fit tight between the girders, and connects the bottom flanges by the rods. Has never observed any injury arise to girders from being subjected to permanent weights for a length of time, or to changes of temperature. Would allow girders on railway bridges to deflect from the $\frac{1}{40}$th of an inch to the $\frac{1}{20}$th of an inch per foot linear. But the amount would depend on the form of the girder. Some forms admit of more deflections than others. Does not like too much deflection in a railway beam. For the forms of girders adopts the large bottom flange. According to his present experience, would limit cast iron girders in one piece to 45 feet long, but he may perhaps go further. Would always prefer an arch if possible. Dislikes cast iron in flat girders at all times and in all spans. Would never use it if he could avoid it. Does not object so much to wrought iron, but would not use that when it could be avoided. Is not favourable to girders combined of separate pieces. Would use the bowstring bridge for large spans. Does not approve of combining wrought and cast iron as done in girders of the Dee Bridge class. But does not wish it to be inferred that there is no combination of which he would approve. Objects chiefly on account of the different rates of expansion of wrought and cast iron. Does not think that in compound bridges well put together the vibration and impact from trains would affect the joints and rivets; but if badly put together, or the roadway were not in good order, the joints would sooner or later be affected. Does not consider that the deflection of one girder before that of the other in skew bridges would produce oscillation to any injurious extent. When the roadway is good there is very little difference between the deflection due to weights at rest and that due to the weights moving with velocity. A bad joint is much more serious than an increase of velocity. Has known the deflection to be less with velocity. When there is any great difference, attributes it to bad joints. Conceives that perpetual concussions might change the texture of wrought iron. Does not think the same effect would be produced in cast iron. A cast iron beam which had been in use for a long time in the Blackwall Railway was taken out and broken; it bore a very large weight with reference to its calculated breaking weight. Would observe that axles broke more frequently when crank axles were in use. The fractures he has seen appeared to be the work of time. He has seen nothing in the fractures to induce him to believe they were the result of a change of structure. Considers one ton per foot in length as the greatest weight that comes on railways; is opposed to increasing the weight of engines. Thinks the plan of having wrought iron box girders a very sound one. They have been long in use for steam engines; prefers them in moderate spans to cast iron. Would never employ a flat girder unless compelled to do so. The effect of the vibration of trains, however slight, is ultimately to separate the parts, while in an arch the parts are always clinging faster together; if a general rule is to be adopted, let it be in favour of the arch.

Charles H. Wild, Esq., Civil Engineer.—In testing the compound girders for the bridge over the Ombrone, an initial strain of 5 tons per square inch of section was put upon the wrought iron ties; by the adjusting pieces, any amount of initial strain can be put on the ties. By that means the beam can be cambered. If, in compound girders, the ties are applied in a neutral state, they are of very little practical use. The ties have an initial strain put upon them, but does not believe that any change will take place in the ties to require re-adjustment. If the strain put upon them is far within the limits of elasticity, they will retain that strain. If an extension of the ties were likely to take place, this sort of bridge should be given up. The ties being strong enough to allow for extra weight to come upon them, will never require to be adjusted after being put up. The bridge over the Arno is of compound girders, with the ties lying horizontally along the bottom flange. The ties are in four pieces, and adjusted to the required initial strain by means of gibs and keys at the junctions. This bridge was tested by taking out the dowels connecting the castings, and allowing the whole strain to come on the tension rods. If the ties are put on in a neutral state, the elongation when the weight comes on is so small that the strain would only be about 1½ ton per inch; the initial strain can be so adjusted that the tie can take the whole of the tensile strain of the girder, or half, or any proportion. The bridge is 96 feet span, and was tested with 40 tons in the centre, trusting entirely to the ties. Has experimented on compound girders with the tie, and when the tie was removed, and has found the stiffness increase with the amount of initial strain put upon the ties. In breaking compound girders, never saw the bolts give way; no strain can come upon them so long as the joints do not open. Looks upon the dowels and bolts as only useful during the course of erection. Would not like to test the Arno girder without the tie, but thinks the bolts and dowels might be taken away without interfering with the strength. In an experimental girder made for the tie to be adjusted, either horizontally or at an angle, like in the Dee Bridge, it was found to be almost equally efficacious in three different positions—viz., when the ends were, 1st, higher than the top flange of the girder; 2nd, level with the top flange; 3rd, horizontal. The effect of the difference between the extreme cold of winter and the extreme heat of summer would be to add about half-a-ton per square inch to the existing strain upon the tie. The useful effect of the tie, when the girder is bearing a load, depends on its area, upon the strain upon it per square inch, and upon its depth below the centre of compression; hence, if the ends of the girder came in so as exactly to counterbalance the extension of the lower part of the girder (a point never reached in practice), if there were an initial strain on the tie, it would still be doing useful work. It is a popular fallacy that there is a disadvantage in having the ends of the ties above the top flange; the raised ties give greater facility for putting on the initial strain than the horizontal ones. The initial strain is measured by means of an instrument called an extensometer, fixed on to the tie bar, which shows the actual amount the bar is extended; and having found the rate at which similar iron extends with certain weights per square inch of section, the strain on the bars due to the extension is known. The higher the tie is put the less increase of strain comes on it from the passing load. Has never known the tie slacken. Does not consider that a wrought iron bar cast into the bottom flange of a girder is a good method, as no initial strain can be put on it. If, by means of the weight, the bar was extended the $\frac{1}{1000}$th of its length, there would be a strain on it of 10 tons per square inch, but has never known them extended beyond $\frac{1}{4000}$th; hence the strain would only be 2½ tons per square inch. The cast iron would break before the tie was doing much work. The above forms of trussed girder are the only ones that have been adopted. Would have the platform of a bridge firmly united to the girders, and sufficiently deep to prevent any twisting in the main girders. The bearers for the platform in the Arno bridge are Sandwich girders. Mr. Stephenson is using strips of wrought iron, with timber between, for purlins for roofs. They are very stiff.

Thomas Cubitt, Esq., Builder.—Has found variations in the same description of iron; experiments by different persons do not give corresponding results from similar makes of iron. Does not trust to experiments made on a small scale. The quality of iron is only affected by the hot or cold blast so far as materials unfavourable to the production of good pig iron are present. Care should be exercised in the selection of hot blast iron. Makes girders strong enough to bear three times the greatest load that could come upon them; these girders are for buildings. Proves girders by the hydraulic press; proves them to double the greatest load that could come upon them, or two-thirds the breaking weight. From the liability of girders to internal flaws, would rather prove a girder nearly to the extent that would break it than not prove it at all. In buildings, the weight is more frequently put on the bottom than on the top flange, but has never thought it of importance to apply the proof weight to the bottom flange. The deflection of a girder depends on the shape, section, and quality of metal. In two girders, the length of one being double the length of the other, but the section and depth being constant, the longest girder would deflect four times as much as the other. Considers the stiffest iron best for steady weight. Weighted a girder with a load equal to two-thirds of its breaking weight, and left it on for 36 hours; the deflection did not increase, and the permanent set was not more than that which had been observed after the first application of the weight. Makes the area of the top flange to the bottom one as 1 to 3½ or 4. The bottom flange is equal in width to about half the greatest depth of the girder; diminishes the depth of the girder at the ends to about half the depth in the centre; considers it of great importance not to do anything which would tend to make the girder unsound when cast, or cause unequal strains in cooling. Shoes or sockets tend to create flaws, by allowing dirt and sand to accumulate, and

prevent the equal flow of metal. It does not follow that the theoretical form of greatest strength is the best one to adopt. His attention has been principally confined to beams subjected to weights at rest. As weight in such castings is not of so much importance, he is guided in the selection of irons by the market price. Always mixes irons; is inclined to think that good will result from Mr. Morries Stirling's endeavours to increase the strength of iron by an admixture of wrought iron. Thinks the manufacture of iron below the other manufactures of the country; believes that in France they roll out bars heavier than we do. Thinks that, if the plan adopted in Belgium of the manufactures exhibiting qualities of iron every year were followed it would improve the manufacture. Considers that the quality of iron depends, first, upon the raw material, then on the fuel and care in manufacture. Thinks investigation into the manufacture of iron desirable, and that it would be advantageous to offer premiums for the best iron.

Isambard Kingdom Brunel, Esq., Civil Engineer.—Has a preference for the Welch and Staffordshire irons. Endeavours to obtain a small proportion of hot blast iron in mixtures. Does not like a large proportion of hot blast; thinks one-fifth advantageous. Takes the greatest possible load that can by any accident come upon a girder, and assumes that as one-third or two-fifths of the breaking weight; but takes the breaking point lower than it is generally taken. As a general rule, would prove a girder with a load a little greater than the greatest that could come upon it, and examines its appearance under that load. Actual weight is the preferable mode of testing girders. Although, strictly speaking, the same load cannot be borne by a girder when resting on one flange as if applied at the top, on account of the torsion, yet, by endeavouring to bring it as near to the centre as possible, has not perceived any sensible difference. If circumstances made it desirable to construct a girder to carry a load on the flange, at some distance from the centre, it might then be desirable to calculate the strength of the girder; would certainly test it in that manner. Such cases have not been sufficiently frequent to require a special provision. Does not believe that any appreciable difference is caused in the power of resistance of the girder. Considers that, with his form of girder, and with a large dead load of ballast, &c., the torsion is inappreciable. A soft substance between anything that produces vibration and cast iron is advantageous, but wooden sleepers to support the roadway should not be so elastic as to press on the edge of the flanges of the girders. Does not consider that a moderate weight left on a girder will ever injure it. Has not observed temperature produce any effect except expansion and contraction. Considers that no weight, except that approaching the breaking one, will permanently affect cast iron. The deflection of a girder does not merely depend on the length. In a girder 30 feet long, 15 inches deep, would allow [illegible] of an inch to a foot. The deflection must depend on the form. About half the before-mentioned deflection would be allowed in a very stiff girder. Makes girders of the inverted T-section with a very large bottom web, and swelling at the top of the vertical web. The length of cast iron girders is limited by what would insure a sound casting; at present considers it to be 30 or 35 feet. When girders are required for spans beyond the limits of simple cast iron girders, would prefer not using cast iron at all. Would prefer timber or wrought iron, or both combined. Would apply wrought iron to increase the tenacity of cast iron framing. Has adopted that method in machinery. In large spans, assuming there is no difficulty in obtaining an abutment, would prefer cast iron in the shape of an arch. Does not think that in a work put together by a good mechanic, with ordinary judgment and proportionable strength, that any vibration would affect the bolts. Considers that the introduction of wrought iron plates into the construction of bridges is the most important step that has lately taken place in engineering; believes that with ordinary care and the improvements which have been introduced into riveting, that the joints may be equal to the other parts of the structure. Does not think that vibration can have any effect on well-made riveting. Rivets should not act as pins or bolts, but like clamps, and hold the plates together by the friction of the one on the other; in that manner the plates may be insured not to break in any part contiguous to the rivets. Considers that the crystalline fractures observed in bars broken by a succession of blows is not the consequence of any internal change in the metal, but that iron breaks with a crystalline or fibrous fracture according to the circumstances under which it is broken; produced several pieces of iron broken, some with a crystalline fracture by a short sharp blow, others with a fibrous fracture by means of a slow heavy blow. The same effects may be produced by varying the temperature of the bar. Considers that when the rails are well laid the deflection will be less from a moving weight than from that weight at rest. Some new engines weigh as much as 35 tons, and occupy a length of 26 feet or 1¼ ton to the foot run. Believes that cast as well as wrought iron varies its strength with the temperature; the colder it is the easier it will break. Thinks that suspension bridges might be applicable to railways. Has once proposed one under very peculiar circumstances. Considers the Indian tension bridge inferior to ordinary suspension bridges. Would only use a lattice bridge when he could not get materials for the component parts exceeding a certain length; if he were obliged to make a bridge of great length with short sticks, it might be one mode of meeting the difficulty.

Edwin Clarke, Esq., Civil Engineer.—Has superintended the Conway Bridge for Mr. Stephenson. It is a wrought iron tube made of boiler plates riveted together as in iron ship building: the span is 400 feet, the extreme depth at the centre is 25 ft. 6 in., breadth 15 feet; the internal breadth and depth are 21 ft. 6 in. and 14 ft. 3 in.; the depth at the ends is 3 feet less than at the centre. It was constructed on a timber platform on the beach of the river Conway, 200 yards from its permanent site, and was floated to its position on six pontoons of 250 tons each, and raised 17 feet to its position by hydraulic presses; its weight is nearly 1,300 tons. It has a bearing at each end of 12 feet, and rests on bed plates and rollers to allow of its expansion from change of temperature. It was commenced at the beginning of 1847 and finished in March 1848. The original idea arose from considering whether a beam could be made large enough to cross a span of 450 feet. Mr. Stephenson had formed beams of separate pieces united by bolts, and had also applied tension rods to some beams formed of separate castings. A cast iron arch was proposed but abandoned, partly on account of interference with the navigation of the straits. Two beams side by side with an ordinary upper and lower flange would make a space, through which if large enough a railway carriage might pass. The first experiments were on round and oval tubes; they changed their shapes when loaded; rectangular tubes did not; that form was therefore adopted. Experiments were made to determine the resistance of wrought iron to compression, that the actual strength of a large tube might be calculated; the power of wrought iron to resist compression increased as the cube of the thickness of the plates: the strength of the tube varied as the square of the linear dimensions. A model tube one-sixth the real size was made at Mill Wall, and broken five or six times, and strengthened at the part it had broken at after every time, till it was considered that the strength was everywhere proportioned to the strain. The thickness of the sides of the tubes appeared to produce very little comparative effect. The difference of elasticity rendered it difficult to apply cast iron to the top of the tube. A bar of cast iron yields twice as much under the same weight as a similar bar of wrought iron, though its ultimate resistance to compression is four or five times as great. If the top of the tube were made partly of wrought and partly of cast iron, the wrought iron would have to bear more than its share of pressure. Cast iron must also be cast thick, which increases its weight, and the places of junction require heavy flanges. The Mill Wall model it was assumed, if increased to six times its linear dimensions, should be 36 times as strong and 216 as heavy. The bottom of the tube was considered as a chain, and the plates were lapped over to make the chain as strong as possible; the rivets were proportioned so that the section of the rivet to be sheared through equalled the section of the plate it connected. The shearing strain of a rivet is as its tensile strain. Cells were put in the bottom of the tube as being the most convenient way of getting sufficient area of section of iron. The cells are kept stiff by angle irons. There are five rows of cells in the bottom of the tube. The bottom has great strength to resist lateral pressure, as the wind. The sectional area of the bottom is to that of the top as 5 to 6. The area of the bottom is 508 square inches; the area of the top 608 square inches. In the small experiments the top had always failed by buckling, but the strength of plates to resist buckling varied as the cube of their thickness, and the top might therefore in the large tube have been of the same area as the bottom; but as the top had always been the part to fail, and the data for calculating the resistance to compression were not so complete as those for the resistance to tension, a little was added to the top; 12 tons to the square inch is as much compression as wrought iron can be safely subjected to. At 10 tons per square inch most iron begins to be perceptibly altered in shape. The first experiments were made before February, 1840. The last Mill Wall experiment was made in April, 1847. The sides of the tube were considered a mass of trellice work so thickly interwoven as to become a solid plate; at every 2 feet two pair of angle irons were placed face to face, and running from top to bottom of the tube, one inside and the other out, like vertical pillars, to keep the top and bottom apart. The side plates are 2 feet broad. These pillars appear to give sufficient rigidity, as the sides of the tube have never exhibited the least alteration of shape. For a distance of 50 feet from each end vertical plates have been added to strengthen the sides, where the strain was considered greatest. At the ends, to prevent any crushing of the sides, strong cast iron frames have been inserted. The side plates in the centre are half an inch thick, but towards the ends [illegible]ths of an inch thick; the bottom plates are half an inch thick in the middle, and a quarter inch thick at the ends: on the principle that the strain on the bottom varies at each point as the rectangle of the segments into which the tube is divided at that point. When the sides of the model tubes were thin near the ends, they invariably buckled there. The resistance of the top cells to compression was never exactly ascertained; wrought iron will not bear above 12 tons compression per square inch. The first cells experimented on were oval; the square and circular were then tried; the iron when thin puckered, but a certain thickness of plate answered equally well to prevent the cells either oval, circular, or square from buckling, and the iron crushed. The cells were made square not because the square form is best to resist compression, but because there were many difficulties in fitting a circular cell in the top of the tube, and lateral strength was wanted to resist the wind, and also all the parts could be more readily got at; the cells are 1 foot 9 inches square, and the plates three-fourths of an inch thick. As regards tension, rivets weaken plates, but rivets increase the strength of plates to resist compression. Plates riveted together generally break at the rivet, though they derive some

strength from the rivet acting like a clamp. The top is a plan of pillars and cells; the section is greater in the centre of the tube than at the ends on account of the greater strain. Found a difference in the wrought iron from different makers. Some irons stretch more than others, though the ultimate strengths are about the same. The ultimate strength of the iron to resist tension averages 20 tons per square inch. A great deal depends on the manufacture of iron; some of the iron is very brittle, but its ultimate power to resist tensile strain is as great as more ductile metal. A twelve-ton press laid on the top of the tube produced no deflection of the iron, and a twelve-ton press fell on the top from a height of 25 feet, and produced no other effect than indenting the place where it fell. The locomotive does not run on the bottom cells, but the rails are on sleepers, supported by transverse plates 6 feet apart; the bottom is very rigid. When the wedges were being taken out to let it take its final bearing, the wedges over a large portion of the centre had been left in by mistake, and it was supported by the bottom being bulged up, which was a very severe test; it did not belly up above 1 inch. The tube weighs 1250 tons without the end castings. When the tube was on its original platform, a straight line was set out along the instrument with a thirty-inch telescope, and holes drilled through. The tube was constructed with a camber of 7 inches, that the deflection might not be unsightly. The deflection is sensibly affected by changes of temperature. The motion caused by a cloud passing over the sun, or a shower, was quite visible by the means of an index. The whole structure was a rectangular tube, 412 feet long, before it was moved to its position; it was floated to its position. When raised, 6 feet at each end were added; the bed for it to rest on was 3 inches of creosoted deal, a bed plate 3 inches thick of cast iron, then another layer of creosoted deal to prevent corrosion, a mass of red and white lead was spread over the timber, one end is thus a fixture; the other is on a bed of iron, which rests on 44 rollers of cast iron, 6 inches diameter, to allow of expansion and contraction. In addition to this, to prevent the sides being injured, the tube is partly suspended by suspension rods riveted to the tube at each end, which pass through girders bearing on metal balls, running in grooves; it is calculated that one-third is suspended, and two-thirds on the rollers. The side of the tube is quite closed. The Conway and Britannia Bridges are on similar principles; the Britannia Bridge has 60 feet more span. The Britannia Bridge is named after the Britannia Rock in the Menai Straits. There is one tube for each line of railway. The calculated deflection of the Conway Tube was about 7 inches, so the tube was cambered to that amount. It actually deflected 7⅞ inches by its own weight. When tested with 300 tons it deflected to 10 4/16ths inches below the original line; on removing the weight it returned to rather more than 6 inches. Probably some rivets had been disturbed. The effect of temperature was found to be very great. The deflections taken at night differed from those taken in the day time. The expansion of the cells at the top causes it to rise. It is painted of a light colour to increase the radiation. The extremes of temperature cannot have an injurious effect, as the motion is only 2 inches over 400 feet span. In raising the tube the strokes of the hydraulic presses became isochronous, and the tube vibrated like a shrinking plank, so that the presses had to be stopped. A train of 100 tons causes three-fourths of an inch deflection, but no vibration. Persons in the carriages don't perceive that it is a tube. There is no increase of deflection since it has been opened for traffic. The deflection is measured by an instrument attached to the side of the tube. There is tremor when a train passes, but no vibration. It interferes with the reading of a telescope. The tremor cannot be perceived by standing or lying on the tube, it is greatest when a cannon is fired from the top.

J. D. Morries Stirling, Esq.—Has studied the chemical properties of iron. Cast iron in this country consists of iron, carbon, silica, some phosphates, and other admixtures which may be considered impurities. Cast iron from Sweden and magnetic ore is purer; it contains less carbon. The strongest cast iron contains 3 per cent. of carbon; a mixture of hot blast No. 1 and cold blast No. 3 will give that proportion, but it would be better for iron with that proportion to be produced at once from the blast furnace. A small portion of arsenic increases the fluidity of iron. The higher numbers of hot blast irons apparently contain more carbon than cold blast. Graphite is commonly to be seen on the surface of No. 1 hot blast, not so frequently in cold. Chemical analysis gives very little difference between No. 1 hot blast and cold blast as regards the quantity of carbon. It appears to be combined in a different manner; generally, Scotch is the most, and Welch the least, carbonaceous iron; Staffordshire is intermediate. Phosphorus gives the hot short quality to wrought iron. Manganese closes the grain of iron; apparently improves the quality; gives it a more steely character; increases the property of being hardened by quenching. It does not give the elasticity of steel. Steel and cast iron are improved by manganese. Berlin iron owes its fluidity to arsenic. Dark iron is usually weak, grey usually strong, and white brittle; black iron when chilled becomes white, although it must be supposed to contain the same quantity of carbon; as a general rule, colour indicates treatment to which iron has been subjected, and, in some cases only, the quantity of carbon. Would employ colour as a test of strength, but not of chemical constitution. To resist a transverse strain, grey iron (not approaching to mottled) would be best; to resist a blow, grey iron, approaching to mottled, would be best. The East Indian iron has many properties of malleable iron; its mixture with other pig-iron improves the quality of the latter; small quantities are used in the patent boiler tube manufactory to improve the iron purchased for making wrought-iron. The best mixture of iron for strength would be, for a large casting, a larger proportion of No. 3 Scotch, Staffordshire, or Welch; for a small casting, a larger proportion of Nos. 1 and 2, and a smaller of No. 3. Numbers of iron are, however, very arbitrary: mixing iron adds very much to the strength. London founders improve their irons by the use of scrap iron. Ordnance and hydraulic presses are made chiefly of No. 3; for a girder, more fluid iron would be required. Iron cast in large masses becomes soft from cooling slowly. Has proposed to improve cast iron by an admixture of wrought iron. There is a chemical combination between the two. The quantity of carbon is diminished. The grain is much closer. A small quantity of wrought iron added to dark grey iron makes it light grey; a large quantity makes it mottled, a larger still almost white. Scotch iron requires most wrought iron, Staffordshire less, and Welch iron least. The proportion for Scotch hot blast is for No. 1 from 24 to 40 lb. per cwt.; No. 2 from 20 to 30 lb.; for No. 3 it is not recommended, as the iron is uncertain in itself. Staffordshire will not bear so much as Scotch; 20 to 30 lb. would be a high proportion for Staffordshire No. 1. Welch No. 1 bears the same as Staffordshire; No. 2 requires very much less. The increased strength of the iron is an advantage mechanically. From an average of experiments the waste in casting was 7 lb. per ton in favour of common cast iron. The iron planes like wrought iron and the castings are more difficult to trim than those of common iron. The first object in proposing the iron was to raise the inferior irons to a level with the best, but has obtained a mixture stronger than the strongest. The improvement on strong irons is not proportionably so much as on weak ones. It seems to bring irons to an average. By adding wrought iron scrap to pig iron, and puddling it, the resulting wrought iron is much improved. Cast iron easily acquires magnetic power, and acquires extreme polarity without the power of attracting small bodies to the degree that steel does. Considers it an advantage that a beam of toughened cast iron need not be so heavy as that of common iron. Has observed instances of alteration in the structure of iron from repeated hammering, and shafts exposed to vibration also crystallise. Considers that, possibly, galvanic action causes the change. Cold hammering gun barrels too much makes them brittle. The mixture of wrought iron with cast is made originally in the pig. The specific gravity is from 7·2 to 7·3; the specific gravity of common iron from 6·9 to 7·2. The centre of a casting should be taken for the specific gravity. Thinks it would be useful to inquire into the generic differences of irons.

Charles May, Esq., Ironfounder.—The difference in the strength of iron appears to consist mainly in the proportion of carbon. A large dose of carbon makes a very tender iron; the strength appears to be greatest when the carbon is in the smallest proportion that produces fluidity. The greatest mixture of irons is preferred. One-third anthracite combined with Scotch is a good mixture for toughness and strength. For small castings a more fluid iron is wanted than for large ones. On account of competition, the cheapest iron is often preferred to the strongest. With the bulk of Scotch iron combines Welch and scrap iron; the mixture is very much reducible to the quantity of carbon. An iron very hard for small castings would be soft from the slow cooling if run into a large mass. Cast iron does not depend solely upon its constituent parts, but upon the bulk into which it has to be run; these varying circumstances constitute the art of the ironfounder in producing the greatest strength without any very definite knowledge, either chemical or mechanical. By annealing, great toughness can be produced [*produced a shaving taken from the edge of an annealed cast iron wheel*]. Hot blast iron ought to be as good as cold; but, in some cases, advantage has been taken of it to work up an inferior material. Since the introduction of the hot blast the quantity of carbon combined with iron is greater. Has not the same confidence for strength in hot blast as in cold blast iron. Has met with hot blast iron as strong as the strongest iron. The public would have no security in cold blast versus hot blast iron. The fact of specifying for a particular quality of iron is almost nugatory; the principle of testing the work when done should be adopted. Knows no certain mode of telling different kinds of iron; the manner in which cast iron is modified by the quantity of carbon it contains is shown by chilling. The main feature as regards iron is a question of the proportion of carbon. Considers Mr. Morries Stirling's mixture very advantageous, particularly for irons too rich in carbon. Would make the breaking weight of a girder three times the greatest load. Considers that railway girders are exposed to severe strains from the new foundations, the violent impact they are subjected to, and the load being laid on and removed suddenly. Would prove a girder to once and a half or twice the greatest load; beyond that there is a chance of damage. Considers that the side strain, from supporting the load on the bottom flange, would prevent the girder bearing as much as if applied on the top. Thinks tests should be applied as the weights are applied, in practice; but girders are bought at the lowest possible price per ton, and ten times the profit would not pay for experiments. Thinks the only limits to the length of simple cast iron girders are practical ones, of handling large masses, and pouring the metal equally to form good castings. If a large number of large girders were wanted, it might be worth while to erect a new foundry for the purpose. Is favourable to wrought iron girders. Considers that wrought and cast iron may be combined so as to produce an advantageous effect. When weight comes on the cast iron the wrought iron should take its share of the load. Considers that, if well made, the joints and rivets of railway bridges would not be injured by the vibration and impact to

which they are exposed. Cites the instance of the beam of a steam-engine vibrating continually without suffering any injury, as an instance of iron not being affected by continual vibration; and mentions, in favour of its being so affected, the fact of a gun, employed to break pig iron across, dropping in two after a series of years. Considers the only security for good work is, to hold the makers responsible for it. Has found great variations in bars of similar metal. Thinks that the breaking weight of a small bar is no index to the breaking weight of a large casting.

Joseph Cubitt, Esq., Civil Engineer.—Is at present constructing the Great Northern Railway. Prefers a mixture of Scotch and Welch or Staffordshire and Scotch irons for large castings, as mixtures are stronger than single irons. Believes cold blast iron to be stronger than hot blast iron. Would make the breaking weight of a girder six times the greatest load. Proves a girder with three times the greatest load likely to come upon it, or half the breaking weight. Proves girders either with the hydraulic press or with dead weight; strikes them while the weight is on with a large wooden mallet. Does not consider a girder would bear so much weight if applied on one of the flanges as if applied at the top; prefers loading the girder at the top if possible. Considers the proportions he adopts as sufficient to compensate for the torsion. Has often tested girders with the load on the bottom flange. Has two girders for each line of way, and supports the rails on wooden bearers. Considers any elastic substance between the rails and cast iron girders of advantage in preventing shocks. Does not consider it likely that girders would increase in deflection after a length of time. Would not like a girder of 40 feet span to deflect more than ½ inch; those he is putting up will not deflect half that amount. Observes the deflections of girders when testing them. Adopts Mr. Hodgkinson's form of girder, but makes the top flange rather larger, to give lateral stiffness. Would not like to go beyond 50 feet for the length of simple cast iron girders. Beyond that span would adopt timber, wrought iron, or the bowstring bridge. Has crossed spans of 100 feet by timber bridges and by wrought iron tubes. Considers a bowstring girder with a cast iron bow and wrought iron tie a very good combination of wrought and cast iron. Would prefer wrought iron or timber. Would use an arch of cast iron if not limited with respect to expense or levels. Does not consider the impact and vibration to which railway bridges are subjected sufficient to injure the joints and rivets. In wrought iron hollow girders take the depth at $\frac{1}{15}$th of the span. Subjects them to the same proof that he does cast iron. Does not observe that they acquire any permanent set. Has put some up at Doncaster of 70 feet span. Has found no difference between the effect produced by a weight at rest on a girder and that due to the weight moving at a velocity over it. Considers the greatest weights running on railways to be engines, they weigh 25 and 30 tons. Something more than half the weight of the engine is on the driving wheels. Has preferred for a viaduct near Welwyn, on the Great Northern Railway, brick arches to iron girders. Approves of the wrought iron girders used in the large spans on the Blackwall Railway. If kept painted they will last for a long time; in some cases, to prevent torsion, a cross piece of cast iron between the tops of two girders is advantageous.

SUPPLY OF WATER TO THE METROPOLIS.

We promised to give an account of the different projects which are now before the public for the supply of the metropolis with water, of a better quality and in larger quantities than the supply now given. There are five schemes—namely, 1st. The Henley; 2nd. The Mapledurham; 3rd. The Watford; 4th. The Wandle; and, 5th. The Kingston.

With regard to the Henley and Mapledurham schemes, there has just been issued a very able report made by Mr. James Walker, the eminent engineer, and Mr. Stephen William Leach, the engineer and surveyor to the Corporation of the City of London; and another valuable report on the Watford scheme has just been made by Mr. S. C. Homersham, the engineer to the Watford Company.

It is not our intention to go into the question as to whether the supply ought to be left to private enterprise or to commissioners; but we must now say that generally we are advocates for the former, and have great aversion to public commissions—particularly if we are to have such a board as is proposed to be constituted by the Henley Bill, than which we cannot conceive one more objectionable could possibly be formed. The Commissioners are to consist of persons to be elected, yearly, by the ratepayers of the several Unions of the metropolis, one for each Union; and these Commissioners are to elect a Commission of seven persons, who are to take the entire management of the concern, and are to receive for their labours the sum of £7,700 per annum between them, out of the water rates. By this mode of election, we are to have the metropolis constantly agitated for all the rated inhabitants of the different Unions to muster together, and go through the farce of electing one Commissioner who is only to be a delegate to elect another representative; and to this irresponsible Commission of seven persons, liable to vary every year, is to be entrusted the outlay of two millions sterling. With regard to the amount of the water rate, there appears to be no limit as to what it will be;—first, the Commissioners will have the power of charging *three pounds* per centum per annum on the annual rack rent of the premises; and, in addition to the said maximum rate, the Commissioners are to have power to charge a proportionate part of whatever sum they may be yearly liable to pay, whether for interest or annuities upon moneys borrowed to pay for the purchasing of the undertakings of the existing water companies.

We have made these remarks on the proposed Henley Act just to show that the scheme can never be allowed to be carried out under such an ill-advised Act. The Act, or rather the Bill, appears to have been drawn with a judgment very different to that shown in the getting-up of the engineering department, which we must say exhibits great labour, great talent, and great judgment.

It appears to us that it will be far better for the House of Commons to appoint a select Committee of the House, first, to examine the different schemes that are proposed, without regard to the Bills to be brought in for the regulation of the supply, and to report to the House which they consider is the best; and whether the supply for the whole of the metropolis shall be confined to one of the schemes, or whether it will not be advisable to have one for the North of the Thames Westward of the City, another for the City and Eastward, and another for the South of the River: by thus dividing the supply, there will not be that great diversion of the waters of the Thames from one portion of the river, as stated in Messrs. Walker and Leach's report.

Looking at the whole of the case impartially, we cannot see why the enormous expenses of forming the New River cut, and all the works connected with that Company, should be lost to the public, a supply might be obtained from the New River head at Chadwell, and the river Lea above Tottenham, quite equal to the supply to be taken from the Thames at Henley or Mapledurham. To do this, it will be necessary to obtain powers to divert the drainage from the land and houses on each side of the cut, and prevent the river from being contaminated. By adopting this scheme, one-fourth of the supply of the metropolis might be confined to the City and the Eastern district; and this would be done without affecting the river Thames.—If this be granted, the consideration will next be which of the three schemes, the Henley, the Mapledurham, or the Watford, is the best for supplying the North-Western district of the metropolis.—For the supply of the Southern side of the river Thames, we have the Kingston and Wandle schemes. The former is put forward with the view of taking the water from the Thames above Kingston, and beyond the influence of the tide; and the latter proposes to take its supply from the Wandle just before the water is discharged into the river Thames; and as the discharge is within the influence of the tide, the withdrawal of the water from that part of the Thames (at Wandsworth) cannot much affect the river, particularly if the supply be confined to the Southern districts.

Having said thus much, we shall now proceed to describe the works of the several schemes. For the Henley and the Mapledurham works, we cannot do better than give the valuable report of Mr. James Walker and Mr. Leach.

No. I.—*The Henley Works.*

The first in point of date is the Henley scheme, notices for which were given in the last session of parliament, but the bill was lost upon the second reading in the Commons, after a debate of some length. As some modifications have since been made we shall confine our description to the plan now proposed and deposited.

It commences by an aqueduct which branches off from the river Thames near Mednunham Abbey, or about four miles below Henley. In its course to London it is first by an open canal 40 feet wide and 10 feet deep, as far as West Drayton; thence 26 feet wide and 7 feet deep, to the river Brent; and thence by two brick culverts, each 10 feet diameter, to West-end, Hampstead.

At Hambledon lock, which is about two miles below Henley, there is a lift or rise of three feet six inches in the navigation. This lock is to be removed, and one erected below Mednunham Abbey, the point of junction of the aqueduct; so that the part of the river between the new lock and the lock above Henley will form a nearly level pool or reservoir, five miles in length, and 88 feet above high water.*

From Mednunham the course of the aqueduct curves round the foot of the high ground, and approaches the Thames below Marlow, proceeds on to

* By high water is always meant the high water of an average spring tide near London, or Trinity standard.

near Cookham, is carried over the Thames by an aqueduct bridge about a quarter of a mile above Maidenhead-bridge, keeps nearly close to the Great Western Railway as far as Bull's-bridge, a length of 13 miles, and for nearly 10 miles by the sides of the Grand Junction and Paddington canals, passes under the Grand Junction Canal at West Drayton, and twice under the Paddington Canal westward of the London and North-Western Railway; the aqueduct then continues through Willesden, under the Edgeware-road, and on to West-end, Hampstead, where it terminates in a large basin. The whole length from Mednunham to Hampstead basin is 33½ miles.

Three large collecting and settling reservoirs, for cases of drought, or of the water being discoloured by land floods, are proposed in the line of the aqueduct: one near Cookham, another near West Drayton, and the third, of 77 acres, near Harrow.

From the Hampstead basin, in which the water will stand 85 feet above high water, it is to be raised by steam power (3,500 horse) into an elevated reservoir, also at Hampstead, which is 250 feet above high water. From this last reservoir large iron mains, extending in various directions on the north side, and over Vauxhall-bridge to the south side of the river, will be connected with and supply the mains and pipes in all the districts of the present water companies, whose works are henceforth to belong to the commissioners of the new works, the shareholders of the old companies being compensated by a fixed interest upon their capital.

The inclination or fall in the surface of the water from Mednunham to the Hampstead basin is calculated by Messrs. M'Clean and Stileman and Mr. Blackwell, the projectors and engineers of the plan, to be sufficient for conveying from the river 200,000,000 gallons in 24 hours as far as West Drayton, and 100,000,000 thence to Hampstead. This last being the quantity supposed to be required for giving "an ample daily supply for the metropolis," is stated to be at least double the present supply by all the companies.

The object of the large aqueduct as far as Drayton is to pass a quantity, when there is surplus in the Thames, into the Grand Junction Canal, and thence into a reservoir at Paddington, 85 feet above high water, whence it will be conveyed into the sewers of London for the purpose of cleansing them. The large addition for the purposes of sewerage would lead to an increased expense if any of the schemes for pumping up the water after passing through the sewers be adopted.

The engineer's estimate is:—

Works for bringing water from Henley to London, including compensation to millowners	£1,000,000
Cost of plant for distribution, in addition to the plant of existing companies	1,000,000
	£2,000,000

And the annual expense as under:—

Rentcharge, as compensation to proprietors of existing companies..	£127,500
Cost of distribution, independently of interest of capital for plant	100,000

No. II.—*The Mapledurham Scheme.*

The other, or Metropolitan Water Supply Company, which has been brought out during the last summer by Messrs. Gordon and Liddell, engineers, proposes to take its supply from the river above Mapledurham lock, which is five miles above the junction of the river Kennet, near Reading, or 17 miles (by water) above Mednunham (the Henley Company's point of abstraction), in which distance there are five locks, the united lift or rise 24 feet above the Mednunham proposed level. An open cut or aqueduct, four and a half miles long, is to convey the water from Mapledurham to Caversham, where four reservoirs, together 100 acres, and 98 feet above high water,* are to be formed for purifying the water upon Dr. Clarke's patent process. Powerful steam-engines are to raise the water from these reservoirs through three iron pipes, each five feet diameter, carried across the river, and then into three smaller reservoirs, at one mile distance from the Caversham reservoirs, and 35 miles from London, and at different levels, corresponding with the levels of the three districts into which the engineers suppose London to be divided—the northern or western district being taken at 120 feet; the centre district, which comprehends the City, at 70 feet; and the south and east district at 10 feet above high water. The highest of the small reservoirs is 233½ feet above high water mark, and the lowest 176½ feet, the mean lift being 100 feet, which will require 1,100 horse-power. The water is conveyed from the small reservoirs by a continuation of the three 5-feet pipes to the Great Western Railway, near Twyford, whence they are laid by the side of the railway, and pass over the Thames at Maidenhead, over the Grand Junction and under the Paddington Canals to near Wormwood Scrubs; here the high level pipe diverges, and passes under, and then by the side of, the North-Western Railway to a reservoir at Primrose-hill of 3½ acres, and 169 feet above high water. The other two pipes, for the middle and eastern levels, continue from Wormwood Scrubs by the side of the Great Western Railway at Paddington, and thence along Westbourne-terrace and Oxford-street into a reservoir in St. Giles's, of ½ acre area, and 114 feet above high water. The third or lowest pipe crosses the Thames at Waterloo-bridge into the southern district. The three great mains, or town reservoirs, communicate with the pipes of the present companies.

The engineer's estimate for this scheme is—

For works	£1,200,000
Annual working expenses	20,000

We come now to consider the effects of the two plans upon the navigation of the river, and in doing so we do not think it right to confine ourselves to what the parties profess as to the quantity they mean to abstract; for if the whole of London is to be supplied from one source there will be no satisfaction until the supply is ample and constant, whether the source be Mapledurham or Henley; and parliament will naturally take this into consideration, and give a preference, so far as quantity is concerned, to the plan which has the greatest certainty in the above respect.

The present supply by the water companies is stated, in a recent publication by Sir W. Clay, chairman of the Grand Junction Company, to be 44,573,979 gallons per day; so that the quantity has much increased since 1834. This has been caused partly by the increase of population, and partly also by the greater supply to each house. Is it not probable that both the above causes, and the demand for water for sewerage and other sanitary purposes, will continue to operate so as to render it prudent to allow for these in any great plan; and to consider the effects which the greatest probable abstraction would be likely to have upon the navigation? It is, however, to be noticed (and this was one of the objects in our describing the main features in the two plans), that the Henley party propose their works to be made at first for taking double the quantity calculated by the Mapledurham Company; and also that the Henley aqueduct, being chiefly open can be enlarged—if ever this should be required—at less cost than the Mapledurham, who have to raise their water to a mean height of 100 feet and then pass it through 36 miles of close pipe. To increase the number of pipes would add materially to the cost, and to double the quantity through the same pipes would require an increase of power much beyond the increase of the quantity.

To compare in detail the merits of the two plans would require us to survey the lines, which your instructions would not warrant our doing; but having said thus much on what may be considered a superiority in the Henley scheme, it is but proper to add that the liability of an open canal to receive impurities into it, whatever care may be taken to prevent this, and also to be partially impeded by ice, are objections to which the Mapledurham is not subject; and if the salubrity of the water be presumed to depend upon its freedom from organic matter the Mapledurham source would appear to be preferable, as in the seventeen miles between the points of abstraction, Henley, Reading, Wargrave, and some villages drain into the river. On the other side of the question, it is to be noticed that the Loddon and Kennet join the Thames below Mapledurham and above Mednunham.

We propose therefore to calculate on the abstraction of 100,000,000 gallons per twenty-four hours stated by the Henley project, which is exclusive of their taking an equal quantity (except in times of drought) for sewerage, as has been stated.

The termination of drought and commencement of surplus in the river, with the works for regulating the additional discharge, should be determined in a manner to be approved, and afterwards inspected and controlled by you.

Now, the effect which the abstraction will have upon the navigation both of the locked part above Teddington and the tidal part between Teddington and London, being dependent on the proportion which the part abstracted bears to the whole of the river water, we have endeavoured by former measurements taken by the late and present Mr. Rennie, by Mr. Simpson, and now by Mr. Blackwell and ourselves, at different times, to ascertain the natural discharge of the Thames during such a drought as not unfrequently occurs.

At Staines, the head of your district, we consider the quantity may be taken at from 350,000,000 to 400,000,000 gallons per 24 hours; and at Teddington (19 miles lower), in which space the Colne, Wey, Mole, and Hog's Mill rivers join the Thames, at from 500,000,000 to 550,000,000; so that, in round numbers, the abstraction near Staines will be one-fourth, and at Teddington one-fifth, of the whole natural discharge of the river. In 1846, a very dry time, it was only 248,000,000 near Staines by Mr. Leach's measurements.

As Mr. Blackwell made the river at Henley, during the shortest water of this year, 345,000,000, it may be fairly supposed that at Mapledurham, which is above the junction of the Kennet, it did not exceed 300,000,000; so that the abstraction of 100,000,000 would be one-third of the whole river during seasons of drought. This is more the business of the commissioners of the upper districts; but if the navigation in their portion of the river be damaged, the effect upon the trade would be nearly the same as if the evil were done in your own district.

To enable us to judge as to the effect of the abstraction, correct sections of the bed of the river, and of the depths and inclinations or slopes of the water in the lengths likely to be affected, were indispensable. We again employed an engineer to complete the levels and sections from Staines to Teddington, which he began in the spring, and Mr. Smith to assist us in the

* There is a want of agreement in the levels which have been obtained from the engineers

surveys for the sections below Teddington. These have occupied considerable time, and have been made with great care.

[Here the report enumerates the locks and weirs, and specifies the depths upon the sills, &c. It then proceeds to speak of the deposit.]

The diminished water would have the tendency to increase the growth of weeds and the settlement of deposit in all the periods, but we think it would not exceed a tendency, as the water is clear during the times of short water; at any rate, it is not a matter which we can reduce to quantity, and the same observations as to effect will apply to the reduction of depth in the length of the periods, some of which are, like the sills, barely sufficient for the barges, the standard summer drought of which is 3 feet 10 inches, and they often exceed this.

The effect of the tideway below Teddington lock comes to be considered separately. This lock when built in 1810, had 6 feet upon its lower sill at low water in times of drought. The removal of London bridge and the deepening of shoals in the river near London have lowered the water so that there is now only 3 feet 9 inches upon the Teddington sill (a reduction of 2 feet 3 inches), and the reduction would be greater if the shoals between London and Teddington were removed; for although these shoals impede the passage of barges they assist in preventing the water over them and up to Teddington from falling lower, which is one of the causes of their not having been removed by you. In this case, therefore, the river water, which follows the descent or ebb of the tide, is valuable, both as respects getting over the shoals and keeping up the water upon the Teddington lock sill. Mr. Leach has calculated that the effect of abstracting 100,000,000 gallons would be to lower the level of the water at the lock and for a distance downwards 7 inches, which would be a real and practical evil.

It is proper to state that the above evil is not, in our opinion, without a remedy, for by the removal of Teddington lock, and erecting a new lock near Kingston, or about a mile or a mile and a half above Teddington, with a sill of sufficient depth there, removing the shoals so as to enable the tide to flow more freely up to the proposed lock, and deepening the river up to it, the abstraction of water would be compensated for, and the navigation of the Thames improved by the greater quantity of tidal water which would flow and ebb at every tide.

By the removal of the Teddington lock to near Kingston, as above recommended, the drains of that and the low grounds near it would empty into the river below the lock, which would, it is considered, be an improvement to Kingston and the low ground near it. The suggestion for the removal of Teddington lock and of the shoals is not new; all that is meant to be said is, that the proposed abstraction for waterworks will increase the necessity for it. It may be observed here that the scour of the river between Teddington and London is very little affected by the sluggish current in times of short water, but is chiefly due to the influence of land freshes, during which the discharge is from four to six times greater. Mr. Leach made the quantity below Staines during the flood in 1848, 1,600,000,000; the Henley abstraction of 200,000,000 would therefore still form a considerable proportion (one-eighth) of the whole discharge even in times of flood. If it be asked whether, if the above improvements, by taking down Teddington lock, were made, and the whole of the river water at the same time preserved, matters would be still better, our answer would be in the affirmative; but it is not to be lost sight of that the object of an ample supply of good water is a very important one, and that if it can be shown that London is not so supplied at present, but that it would be by either of the two plans under consideration, the damage which the navigation would suffer would be but small if the means for lessening it which we have referred to were adopted: and we cannot suppose that the parties who were promoting the water supply would be unwilling to carry into effect the measures that may appear reasonable for preventing injury to the navigation through these operations.

The engineers of the two plans agree that the season of drought will be prolonged by these works, and that the evil of such a drought will be increased. Messrs. Gordon and Liddell propose a remedy by means of moveable weirs. We think that a more simple one may be applied in your district; but as the evil is agreed, we do not apprehend there can be much difference of opinion as to the remedy. It must also be admitted that by the substitution of tidal for river water in a part of the river the quality of the water will be less pure than at present.

We have not all referred to the numerous other new plans for supplying London from other rivers and sources, although we understand that notices have been given for some of them, which we were not, until very recently aware of, our instructions not having specified them. Our present impression, however, is that none of them would furnish that abundant supply which we are disposed to consider indispensable, if a general reform, or rather revolution, is to take place in the present system of water supply. As to the effect of these plans upon the navigation, if the water be taken from the Colne or any other river that falls into the Thames, which is the great drain and recipient of all the springs in the strata that incline towards it, the effect is injurious in a greater or less degree, according to the quantity and the distance up the river at which the abstraction may take place.

We beg to conclude by stating that the Grand Junction, the Chelsea, the West Middlesex, and the Lambeth Water Works, all take their water from the Thames, so that the new plans would be partly a substitution and partly an addition, but the present companies' supply is from places so low down the river as to be comparatively harmless. This character, however, would not apply so fully to the Lambeth Company, when their power to take 20,000,000 of gallons per day from Thames Ditton, which is above Teddington, shall be carried into operation; and it is natural to suppose that although the present companies take water from the river so low down as to be less injurious to navigation than either of the present schemes, the tendency will be to follow the example of Lambeth in going higher in order to silence the complaints of their customers as to the quality of the water now furnished.

No. III.—*The Watford Project.*

This project has for its object the taking of the supply of water direct from the bowels of the earth, without allowing the springs to overflow into the rivers to be contaminated, or to be discharged into the sea. From experiments made in the years 1840 and 1841, under the direction of Mr. Robert Stephenson, it was ascertained that a well sunk in Bushey Hall Meadows, only 34 feet deep, with four 5-inch borings to the depth of 190 feet, yielded upwards of 1,800,000 gallons per day, which clearly proved, that by more extended works, an immense supply might be obtained. Mr. Stephenson proposed to sink wells to the depth of 100 feet, and lift the water to about 50 feet above the surface of the Meadows; and then to convey the water, by means of a brick culvert, driven through the hills between Edgeware and Bushey, to a field on the north of Edgeware, where a large reservoir was to be formed to receive the water, whence it was to be conveyed by means of large iron pipes, along the turnpike-road to a hill near West-end Lane, where distributing reservoirs were to be formed on three different levels (the highest about 180 feet above Trinity high-water mark), and thence the water was to be conveyed, by means of iron mains, to different parts of the metropolis. These reservoirs were of sufficient elevation to supply all parts of the metropolis. For supplying the high ground about Hampstead, an auxiliary engine was to lift the water from the most elevated reservoir, and force it up to a higher reservoir. By this plan the whole of the water, excepting for Hampstead, was only to be lifted 50 feet above the level of Bushey Hall Meadows. The total length of the work, the culvert, and main pipes from the wells at Bushey to Edgeware-road, corner of Oxford-street, was between 14 and 15 miles. This plan, in our estimation, was more economical than the one now proposed by Mr. Homersham.

Mr. Homersham proposes to lift the water from the well to be sunk at Bushey Hall Meadows, and convey it by iron pipes to two reservoirs to be constructed at three miles distance, on Stanmore Heath, at an elevation of 390 feet above Trinity high-water, the water having to be lifted 200 feet above the Meadows. At Stanmore the two reservoirs were to contain collectively 70 millions of gallons. The water is to be then conveyed from these reservoirs, by iron mains, along the turnpike-roads, to another reservoir (to hold 24 million gallons) to be formed at Child's-hill, near Hampstead, 302 feet above Trinity high-water, and from it a large main is to convey the water along the Finchley-road to Oxford-street; and thence the water is to be distributed by branch mains to various parts of London. The reservoir at Child's-hill commands a district at least 110 feet above the reach of any existing company. Another high service reservoir is to be formed at Stanmore, at an elevation of 490 feet above Trinity high-water, to supply Hampstead, Elstree, Highwood-hill, Totteridge, Harrow, Stanmore, &c. At three of these places other reservoirs are to be formed, making in all seven reservoirs. By distributing the reservoirs they can be supplied from the mains at different times of the day and night. By these works it is proposed to supply the metropolis with eight millions of gallons per day for 40,000 houses, at 170 gallons daily, and leave 1¼ million gallons for wholesale consumers.

The cost of forming these works Mr. Homersham estimates at 340,000*l.*, and the annual expenses at 15,725*l.*, which includes 9,900*l.* as the cost of pumping the water, and the wear and tear of engines, which will make the expense of pumping 2s. 6d. per annum per house, supplied with 100 gallons per day, which is what we stated could be done.

From our knowledge of the experiments that were made under the direction of Mr. Stephenson, we fully believe that a very large supply of water, of undoubted purity, may be obtained from wells sunk in Bushey Hall Meadows, which will be sufficient for a very large district of the metropolis.

If the works could be carried out as suggested by Mr. Stephenson, and with some trivial improvements, we should have no hesitation in pronouncing the Watford scheme as in every respect the best for the supply of the western division of the metropolis.

We now come to the supply of water for the districts South of the Thames:—

No. IV.—*The Kingston Project*,

Which proposes to take its supply from the river Thames, above Kingston, and above the influence of the tide, where settling and filtering reservoirs are to be formed and engines placed for lifting the water; and thence the water is to be conveyed by 30-inch mains to the reservoirs of the Lambeth Waterworks at Brixton.

No. V.—*The Wandle Project*

Is to take the supply from the river Wandle, at the head of the last mill, before the water is discharged into the river Thames, and to lift the water to a reservoir to be formed on Wimbledon Common of sufficient elevation to supply the whole of the Southern districts; and thence the water is to be conveyed by 36 and 30-inch mains as far as the Elephant-and-Castle, and then branch mains are to radiate through the different parts of the district.

For the purpose of preventing the Wandle being contaminated by drainage or any impurities, a sewer is to be constructed from Croydon to the Thames, with branch drains to intercept all the drainage from Croydon and other towns and houses that now drain into the river Wandle, and also to convey the impurities from the different mills: by this means the water of the river will not be contaminated by drainage. It is well known that the water of the Wandle is from the chalk formation, and is of remarkable purity, and was one of the sources proposed by Mr. Telford for supplying London.

We believe that we have gone through the several projects that are now before the public, and it is our sincere hope that Parliament will thoroughly examine the whole, and not allow the supply of water to the metropolis to remain any longer a disgrace to the nation and to the legislature. It is needless for us to enter into the question as to how the present companies obtain their supply, as it has been so ably exposed in the columns of the *Times*, and is unmercifully condemned by the public.

WATER FROM THE CHALK FORMATION.

Sir,—In the December number of your excellent *Journal*, I endeavoured to show that the lowering of the water-level of the wells sunk under London through the blue clay to the chalk, must arise from the condensed and impervious chalk underlying the London clay, and communicating with the Upland chalk, and not from any deficiency of water in the chalk hills surrounding London to the north, west, and south.

This is confirmed by the fact that the chalk under London communicates with an area of more than 4,000 square miles of Upland chalk, barely covered with a porous soil; and that ½-inch of water in depth per annum over only one-half of this area finding its way under London, would yield 19 *millions of gallons of water for every day in the year*,—while the total amount of water lifted from the deep wells under London at the present time, there is reason to believe, does not exceed 10 millions of gallons per day.

The amount of saline matter contained in the water yielded by different deep wells under London varies, according to Brande,* from 38 to 69 grains per gallon. The base of this saline matter is principally soda, which seems to prove that a large portion of the water beneath the London clay is derived from salt water. As the chalk formation communicates with the bed of the Thames, from Woolwich to Gravesend, and also under the sea, this is easily accounted for by supposing that the water in the chalk underlying the London clay is fed to some extent from this source.

At any rate, it is perfectly evident from the lowering of the level of the water pumped from the chalk below London, when so inconsiderable a quantity is raised, that a very partial communication, if any, exists between the upland water and that procured below the London clay.

S. C. Homersham.

10 *Buckingham-street, Adelphi,*
January 26th, 1850.

* See Quarterly Journal of the Chemical Society of London for January, 1850. Hippolyte Bailliere, 219, Regent-street.

SOUTHAMPTON ARTESIAN WELL.

Sir—As artesian wells are now become a subject of constant discussion, and as allusion is frequently made to the experiment on Southampton Common, it may not be without interest to your readers to state the progress and present state of that incomplete undertaking.

Southampton is situated in the centre of the great chalk basin, of which the rim may be traced along the downs of the Isle of Wight, thence under the channel to the Dorchester coast,—from Dorchester through Salisbury to Winchester, and thence to the coast of Sussex.

Leaving geologists to determine—which they seem unable to do—the probability of our obtaining an abundant supply of water either from the chalk or the green-sand, I shall confine myself to a few figures and facts.

The London clay was reached by penetrating 78 feet from the surface, through alluvial clay, gravel, and sand, the rush of water and loose sand being kept back by an iron cylinder 14 feet in diameter at first, but narrowed, at different stages, to 8 inches, at 465 feet below the surface. The thickness of the London clay formation is 304 feet; it is of all degrees of consistency, from the loosest sand to the hardest stone, abounding throughout in the usual fossils, beautifully preserved. A thickness of 97 feet of plastic clay brings us, at 479 feet from the surface, to the chalk, and into this a 4-inch bore has been carried to an additional depth of 781 feet, without any important increase of water: during the time of pumping, the water continues within 80 feet of the surface, rising to 40 or 50 feet when not interfered with. By pumping from this depth, 30,000 cubic feet daily may be obtained.

The present depth was attained in 1846, since which time the boring has been discontinued. Very lately, however, a contract has been signed with Mr. Clark to continue the boring 300 feet. I apprehend, however, that progress will be stayed until the Report of Mr. Ranger has been printed and circulated. That gentleman has lately instituted an inquiry, as Inspector under the Health of Towns Act, into the sanitary condition of Southampton, which he has conducted with admirable judgment and laborious investigation. His impartiality, moral weight, and scientific knowledge, have gained the confidence of all parties; and we anticipate that, acting under his advice, we shall avail ourselves to the utmost extent of the advantages which nature has abundantly conferred upon our locality.

John Drew.

Southampton, Jan. 26th, 1850.

FARM DRAINING AND WATERING.

We extract the following from a paper on "*Watering of Farm Fields in Periods of Drought, and for the Distribution of Liquid Manure by Pumping, and a System of Pipes*," by Mr. Smith, of Deanston, which lately appeared in the *North British Agriculturist*:—

The farmer, although, no doubt, it must have frequently occurred to him that much benefit would arise from the command of moisture, yet, without possessing the knowledge necessary to enable him to ascertain the practicability of applying water, artificially, over his vast fields, smothers his wish with a sigh, and makes no further inquiry on the subject. It is for those who have the knowledge of the whole subject to make the inquiry; and, from peculiar circumstances, I have been enabled, not only to make the inquiry, theoretically, but to have it put in practice; and I shall now enable you to lay before your readers an outline of this important improvement.

The pumping of water and the conveyance of it in pipes costs a much smaller sum than most people have any idea of; and there is no limit, within fifty miles, to which it could not be transmitted. It has been ascertained, from many practical workings, on various scales, that the mere working of a steam-engine, to pump water where coals are about 10*s.* a ton, will not cost more than 1*s.* for 30,000 gallons, raising it 100 feet high; of course, every additional 100 feet it is raised will cost as much more. The cost of laying down the permanent pipes, necessary for conveying and distributing the water upon the ground, will amount to about two pounds per acre, provided that pottery-ware pipes are used, which kind will be found quite sufficient, where the pressure does not exceed 300 feet of water. In districts where there is high land within a distance of ten miles, the water may be collected and stored in